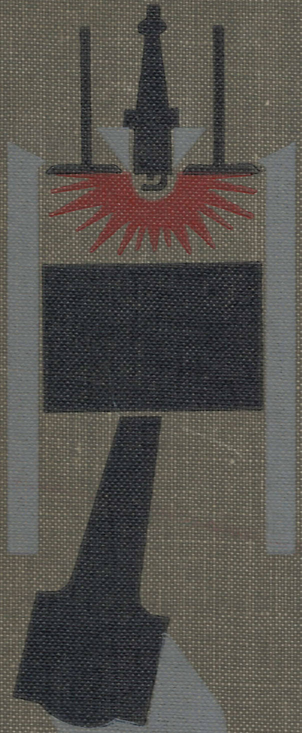

Motor Service's

automotive encyclopedia

construction, operation,
service, and repairs

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automotive encyclopedia

fundamental principles, construction, operation, service, repairs

Edited by

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INTRODUCTION

The automotive service field offers excellent opportunities for men with the necessary educational background and practical training. A good mechanic is well paid, and his work is always in demand.

MOTOR SERVICE'S AUTOMOTIVE ENCYCLOPEDIA is a book of Fundamentals and Basic Service Procedures--the foundation on which a sound, thorough knowledge of auto mechanics is based. The mechanic with a knowledge of these important fundamentals is not "tied" to a shop manual; he has the know-how which will enable him to quickly diagnose trouble and provide the service or repair needed on any make of car--any model--at any time.

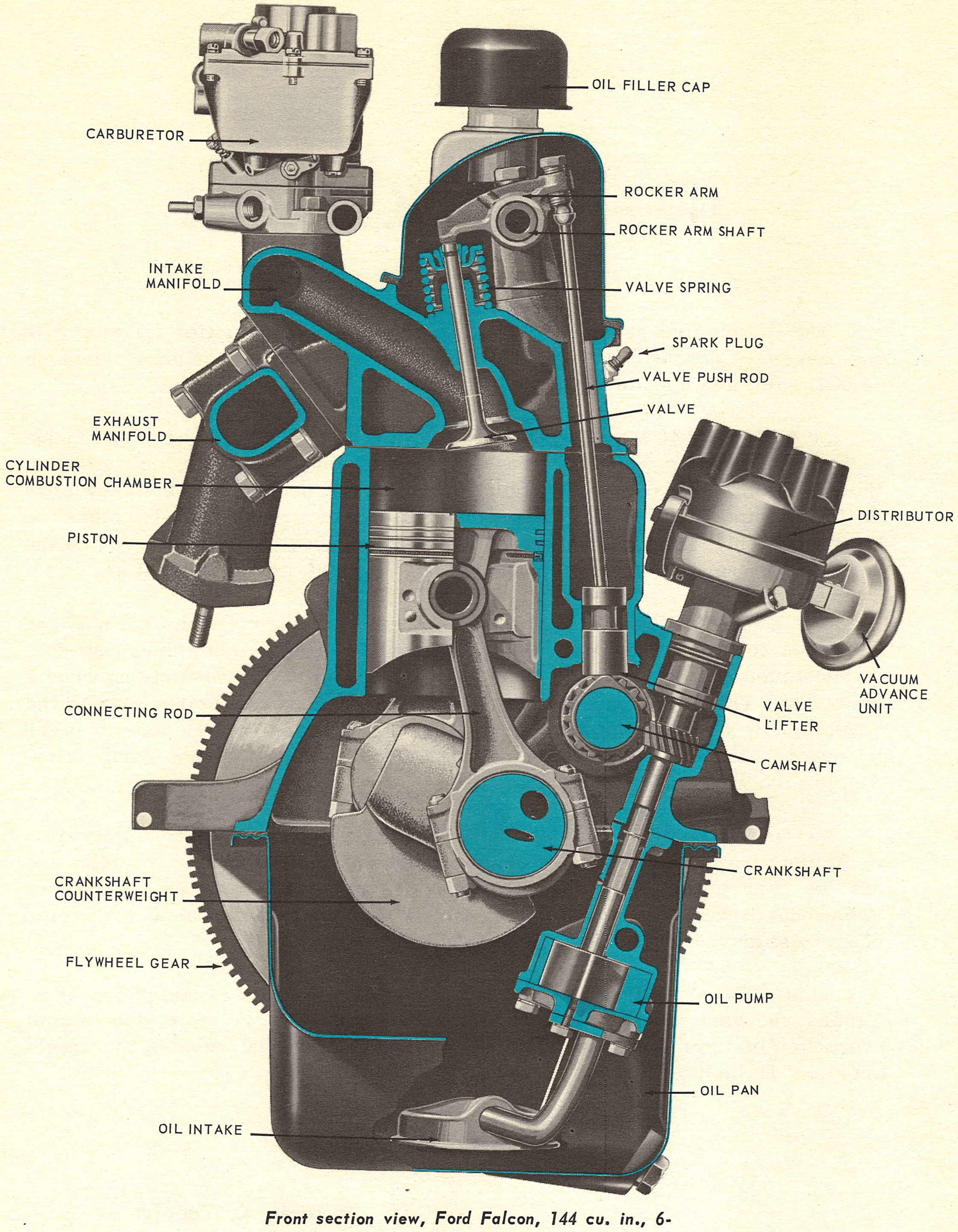
The ENCYCLOPEDIA tells, and shows by clear illustrations, what happens when you turn on an ignition key and "step on the gas" -- how energy in fuel is converted into power, and the power is transmitted to the driving wheels of a car. This book describes the accessory parts that contribute to the development and utilization of that power. It covers the sciences involved in the repair and maintenance of the modern car--Internal Combustion, Electricity, Hydraulics and Pneumatics.

MOTOR SERVICE'S AUTOMOTIVE ENCYCLOPEDIA provides instruction in Automotive Mechanics, as recommended by the standards for Automotive Service Instruction in Schools prepared by the Automotive Industry--Vocational Educational Conference. It covers, also, numerous other topics of interest and practical value to the auto mechanic.

This book is intended, too, as a guide for car owners and prospective owners who want to learn about cars so they can achieve reliable, economical operation of their own cars, and better handle any emergencies that might arise on the highway.

William K. Toboldt

Jud Purvis


OIL FILLER CAP
CARBURETOR
ROCKER ARM
ROCKER ARM SHAFT
INTAKE MANIFOLD
VALVE SPRING
SPARK PLUG
VALVE PUSH ROD
VALVE
EXHAUST MANIFOLD
CYLINDER COMBUSTION CHAMBER
DISTRIBUTOR
PISTON
VACUUM ADVANCE UNIT
VALVE LIFTER
CONNECTING ROD
CAMSHAFT
CRANKSHAFT
CRANKSHAFT COUNTERWEIGHT
FLYWHEEL GEAR
OIL PUMP
OIL PAN
OIL INTAKE

Front section view, Ford Falcon, 144 cu. in., 6-cylinder engine, with principal parts identified.

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TOOLS, MEASUREMENTS, FASTENERS

TOOLS

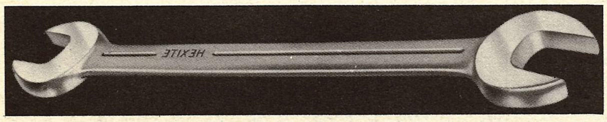
Hand tools, measuring devices, and fastening methods form a most important part of every automotive repair job.

Hand tools are used on every job to remove, disassemble or adjust parts and units. Measuring devices are a must for checking sizes and clearances. Various types of fasteners such as bolts and nuts, are used to hold the parts together.

It is therefore essential that every mechanic be thoroughly familiar with the tools, measuring devices, and fastening methods that are used in the automotive industry. In addition, it is important to know the correct methods of using tools and measuring devices, not only to be able to complete the work as quickly as possible, but also with maximum accuracy and safety.

OPEN-END WRENCHES

Probably the most important tool in a mechanic's kit is the open-end wrench. These are used for loosening or tightening bolts and nuts, and an example of one of these wrenches is illustrated in Fig. 1-1.



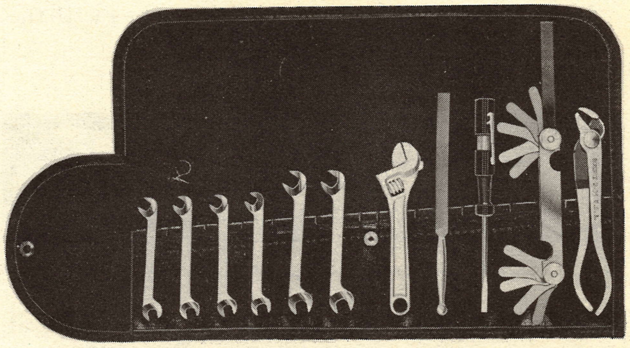
1-1. Example of typical open-end wrench.

Wrench sizes are designated by the width of the opening. And a set of standard open-end wrenches usually has the smallest opening of 3/8 in. and increases in size in 1/16 in. steps with the largest opening of 1 in. Larger openings are also available, but are not always included in a set.

In order to be able to turn a nut in a restricted space, the end of the wrench is placed at an angle to the handle. Usually this is 15 deg. By having first one side of the wrench up, and then the other, it is possible to turn nuts in very restricted spaces.

Wrenches are also made with openings at 22 1/2 deg., 30 deg., 60 deg. and 90 deg. to the handle.

While the smallest opening of a standard wrench set is usually 3/8 in., smaller wrenches known as miniature, Fig. 1-2, are also available.



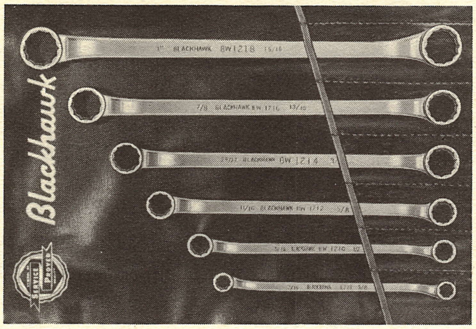
1-2. Set of special open-end wrenches with other tools comprising a set for ignition work.

Such wrenches are needed for work on ignition systems, etc. The openings range in size in 1/32 in. steps from 3/16 in. to 15/32 in.

Special open-end wrenches designed specifically for adjusting valve tappets on L-head engines, are also available. These wrenches are thinner and longer than the conventional open-end wrench, and five sizes from 3/8 in. to 5/8 in. are the openings usually provided.

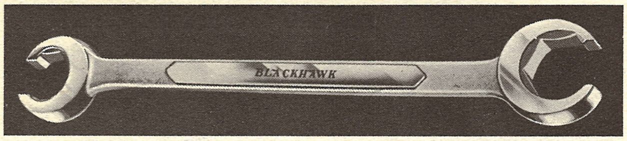
BOX WRENCHES

In order to reduce the possibility of a wrench slipping from the nut, the box-type wrench, Fig. 1-3, was designed. Usually the box is a double hexagon (12 grooves). These grooves engage the corners of the nut. This permits moving the handle of the wrench through an arc of as little as 30 deg. The wrench can then be repositioned on the nut. This is an extremely important advantage, as the movement of the wrench handle is often restricted because of space limitations. Furthermore, as the walls of the box are relatively thin, less space surrounding the nut is required than is the case with the conventional open-end wrench. The disadvantage of the box wrench is that it cannot be used on copper tubing fittings. However, a box-type wrench, Fig. 1-4, with a section of the box cut away, is available for such work.

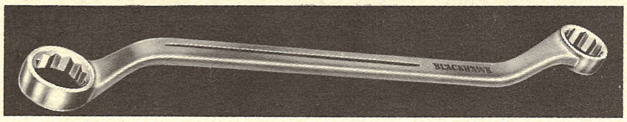


1-3. *Set of box-type wrenches.*

In addition to the regular box wrenches with the straight handles, some have the heads set at angles of 15 deg. to the handle, Fig. 1-5. This tips the end of the wrench which is not on the nut upward, and provides clearance for the mechanic's knuckles. There are also many wrenches designed for specific jobs. Fig. 1-6, shows a special wrench designed especially for work on manifold units.



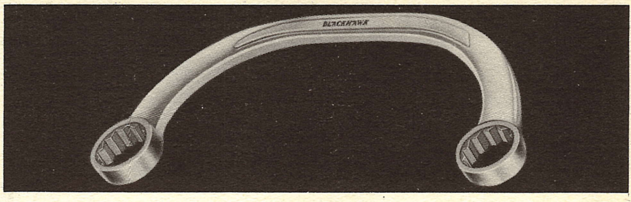
1-4. *Special wrench for working on copper tubing fittings.*



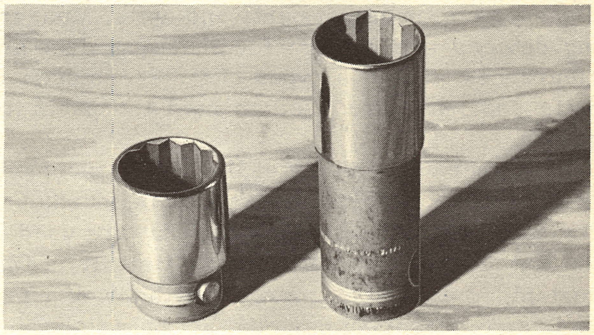
1-5. *Box-type wrench with head at 15 deg. to handle. The offset provides clearance for mechanic's knuckles.*

SOCKET WRENCHES

Socket wrenches, Fig. 1-7, like the box wrench, completely surround the nut to be tightened or loosened, and in that way there is little chance of the wrench slipping from the nut. With assorted handles they greatly reduce the time for removing nuts. Usually the socket wrench used in automotive work has 12 grooves to engage the corners of the nut. Socket wrenches come in sizes from approximately 3/16 in. to 1 5/8 in.



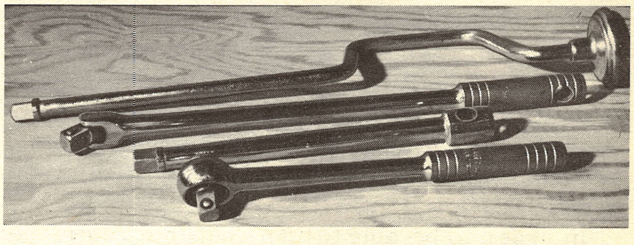
1-6. *Special wrench for working on exhaust manifolds.*



1-7. *Conventional socket on left and deep socket on right. When used for spark plug removal, the deep type is provided with a rubber insert which grasps the plug for easy removal.*

Socket wrenches as used in automotive service work have detachable handles of various types, Fig. 1-8. The drive opening of the socket, that is the opening in the socket in which the wrench handle is placed is 1/4 in., 3/8 in., 1/2 in., or 3/4 in. square. This is known as the "drive." In addition, one manufacturer has a socket wrench with 7/16 in. drive, which is designed to take the place of both the 3/8 in. and 1/2 in. drive socket sets.

Mechanics usually have a set of 1/4 in., 3/8 in., and 1/2 in. drive socket wrenches in their kits.

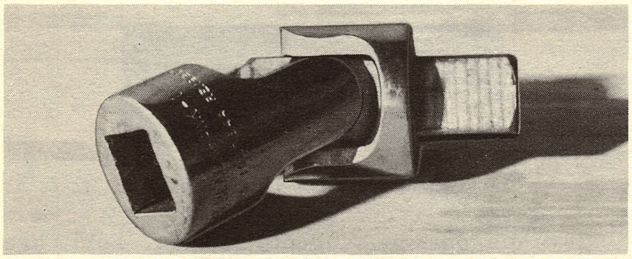


1-8. *Assorted socket wrench handles. From front to rear: Ratchet, extension, flex handle and spinner.*

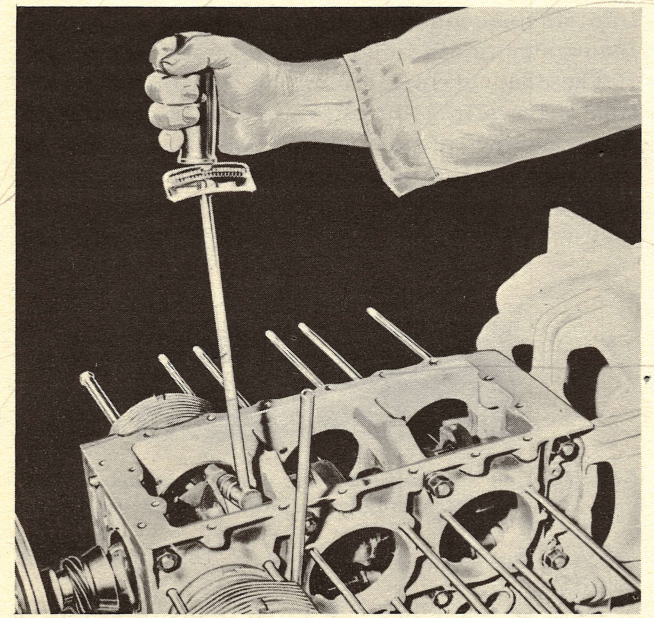
The 1/4 in. square drive socket set usually includes sockets ranging in size from 1/4 in. to 7/8 in. And the 1/2 in. square drive socket set is designed for use on nuts ranging in size from 3/8 in. to 1 5/16 in.

In addition to the various size sockets of standard depth which are used for loosening and tightening conventional nuts, extra deep sockets are also available, and are used primarily for removing spark plugs.

A socket wrench set also includes various types of handles, which are so designed that nuts in normally inaccessible positions can be reached, and as a result the time for their removal and replacement is greatly reduced. The following types are usually included: reversible ratchet handle, extensions of various lengths, speeder, cross handle, hinge or flex handle, Fig. 1-8.


1-9. A universal joint is used to provide an angle drive.

Inside the head of the ratchet handle, Fig. 1-8, is a pawl or dog which engages or fits into one or more of the ratchet teeth. Pulling on the handle in one direction, the dog holds in the ratchet piece and turns the socket. Moving the handle in the opposite direction, the dog ratchets over the teeth, permitting the handle to be backed up without moving the socket. As the teeth of the ratchet are relatively fine, the ratchet handle can be swung through a very small angle or arc in order to get a new grip. By using a ratchet handle, it is not necessary to disengage the socket from the nut, and in that way the nut can be quickly removed.


1-10. Using a torque wrench on a Corvair connecting rod bolt.

The speed handle, which is shaped like a carpenter's brace, Fig. 1-8, is also designed for quick removal of the nut, and is used primarily after the nut has once been loosened by means of another wrench providing greater leverage.

In many cases it is not possible to get a direct pull on a nut, and then a universal joint, Fig. 1-9, is used between the handle and socket.

TORQUE WRENCHES

In many cases it is essential that a nut be tightened to a specified amount. If overtightened, the part on which the nut is mounted may be distorted and leakage of some sort may occur. This is particularly true in the case of cylinder head and bearing nuts and bolts. So that such nuts or bolts can be tightened to the specified amount, a torque wrench, Fig. 1-10, is used. Torque wrenches are provided with an indicator which will show the amount of torque in either foot pounds or inch pounds. When using a torque wrench, it is imperative that the threads of the nut to be tightened be clean and oiled, so that no additional friction will be present.

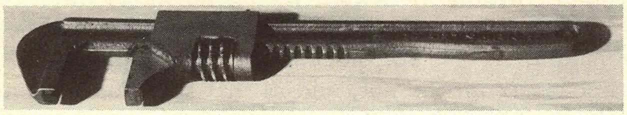
1-11. Adjustable-end wrench.

Torque wrenches are used with the socket of the size to fit the nut which is to be tightened.

ADJUSTABLE WRENCHES

There are three general types of adjustable wrenches. These include the adjustable-end wrench, Fig. 1-11, the monkey wrench, Fig. 1-12, and the pipe or Stillson wrench, Fig. 1-13.

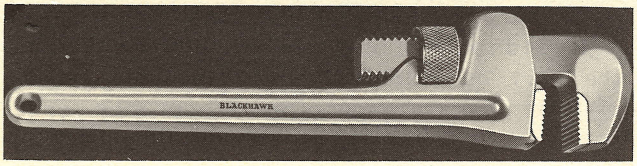
The adjustable-end wrench and the monkey wrench are convenient to have in a mechanic's kit, as they will fit any nut which is within the range of their adjustment. They are available in various sizes, and are specified according to their length. The main disadvantage of these two adjustable wrenches is that they do not hold their adjustment. Consequently they are apt to slip on the nut.



1-12. Monkey wrench.

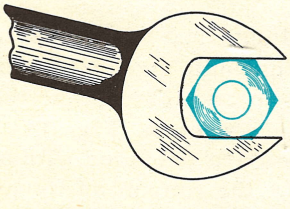
The pipe or Stillson wrench, as the name implies, is designed specifically for tightening and loosening pipes or other circular items.

Pipe wrenches are seldom needed in automotive work, but occasionally they are found necessary on nuts which have been so damaged that conventional wrenches will not hold on them.

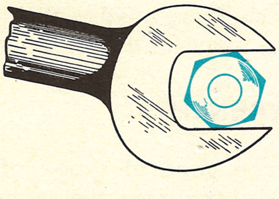


1-13. Stillson wrench which is used for pipe work.

Regardless of what type of wrench is being used, be sure that it fits the nut or bolt head, Fig. 1-14. If the wrench opening is too large for the particular nut, Fig. 1-15, it will slip and round off the corners of the nut. In addition, when the wrench slips, the mechanic may receive a skinned knuckle. It is always much safer to pull on a wrench than to push on it.



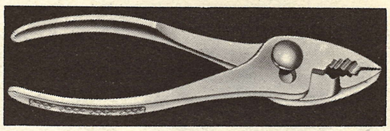
1-14. Care must be taken to select wrenches that fit the nut exactly.



1-15. If wrong size wrench is used, corners of the nut will become rounded, then even the correct wrench will no longer fit.

PLIERS

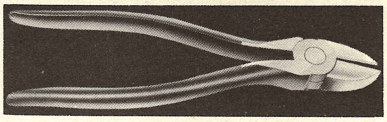
There are many different types of pliers used in automotive work. One of the most commonly used pliers in the automotive field is the 6 in. combination slip-joint plier, Fig. 1-16. The slip-joint permits the jaws to be opened wider at the hinge for gripping larger diameters.



1-16. Combination slip-joint plier.

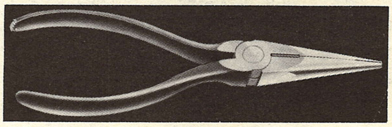
The diagonal cutting pliers, Fig. 1-17, are needed not only for cutting wire but are also used extensively for removing cotter pins.

Long nose pliers, Fig. 1-18, either the flat nose or duck bill type, are needed frequently in recovering a washer or a nut which has dropped into an inaccessible place, and are also used frequently to aid in positioning small parts.



1-17. Diagonal cutting pliers are used not only for cutting wire, but also for pulling cotter pins.

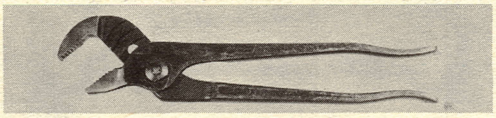
The channel-lock plier, Fig. 1-19, is a variation of the slip-joint plier in that it is adjustable. The opening of the plier can be adjusted to several different sizes, by means of a dog which engages any one of the circular channels. In that way the jaws of the plier remain approximately parallel regardless of the size of the opening.



1-18. There are many different types of long nose pliers. These are used frequently for positioning small parts.

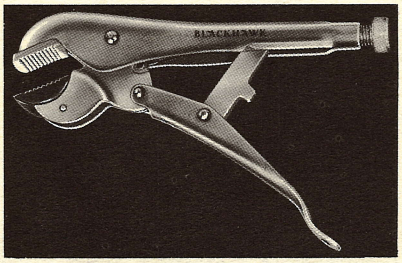
One of the most versatile tools in the mechanic's kit is the vise-grip or locking plier,

Fig. 1-20. When locked in position on a part, it will grip it firmly even though the area contacted by the jaws of the pliers is extremely small. It has an infinite number of uses ranging from holding two parts together while they are being worked on, to gripping the end of a broken stud and turning it out of its threaded hole.



1-19. Channel-lock pliers are not so apt to lose their adjustment and their jaws remain approximately parallel throughout their range.

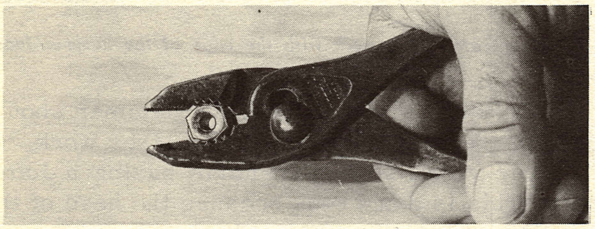
Pliers and Stillson wrenches should never be used for loosening or tightening nuts, Fig. 1-21.



1-20. Locking or vise-grip pliers are one of the most important tools in a mechanic's kit.

SCREWDRIVERS

Many different types and sizes of screwdrivers are needed by the automotive mechanic. The conventional screwdriver, Fig. 1-22, has a flat blade designed to engage a straight groove in the head of the screw.

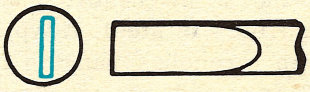


1-21. Pliers should not be used for loosening or tightening nuts.

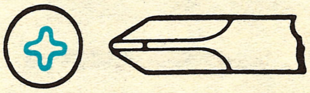
The Phillips-type screwdriver, Fig. 1-23, has a pointed end with four grooves which are designed to engage corresponding slots in the head of the Phillips-type screw.

Another type screwdriver is the clutch-type screwdriver, Fig. 1-24, with a fluted end designed to engage a corresponding opening in the head of the screw.

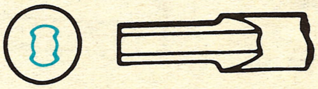
The usual length of screwdrivers is 3, 4, 6, 8, 10 and 12 inches. A complete set is essential.



1-22. Conventional screwdriver.

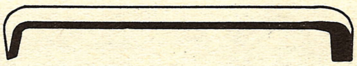


1-23. Phillips head screwdriver.



1-24. Clutch type screwdriver.

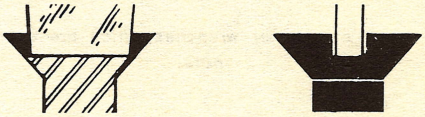
When the space over the head of a screw is limited, an offset screwdriver, Fig. 1-25, is needed to remove or tighten the screw. These are available in different sizes, and can also be obtained with ratchet heads.



1-25. Offset type of screwdriver is needed when there is little clearance over the screw head.

Screwdrivers should only be used on screws. The blade of the screwdriver should fit the slot in the screw, Fig. 1-26, and the blade of the screwdriver should always be held vertical to the screw head.

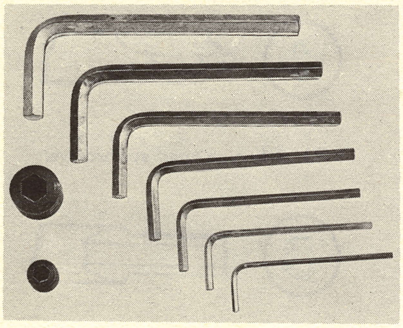
Screwdrivers are not designed to be used as levers or pry bars. If a pry bar is not immediately available and a screwdriver must be used, be sure that the screwdriver selected is strong enough to stand the strain without bending. Screwdrivers should fit the screw slot snugly, as a loose fit will not only damage the screw head but also the screwdriver blade.



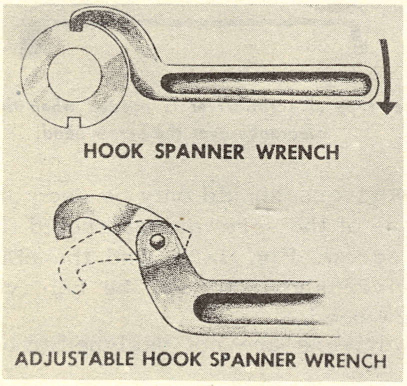
1-26. The screwdriver blade must always fit the slot in the screw.

SETSCREW WRENCHES

Setscrew wrenches, or Allen wrenches, Fig. 1-27, are used on setscrews with hexagonal recesses in the screw heads. These wrenches are L-shaped bars of steel. A typical set comprises eleven wrenches ranging in size from .050 to 3/8 in., and are designed to fit set screw sizes #4 to 3/4 in. Spanner wrenches, Fig. 1-28, are used to tighten and loosen round nuts which have a series of notches cut into the outer edge. For the most part, these are special wrenches furnished by the manufacturer to service special parts.



1-27. Set of setscrew wrenches, also known as Allen wrenches, with setscrews on left.

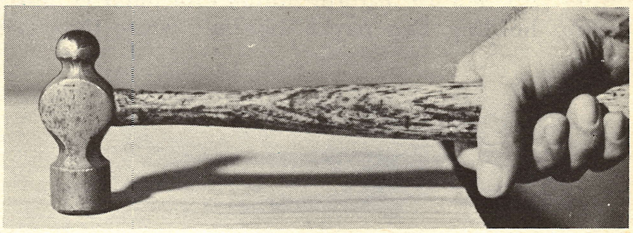


1-28. Two types of spanner wrenches which are used on radial nuts.

HAMMERS

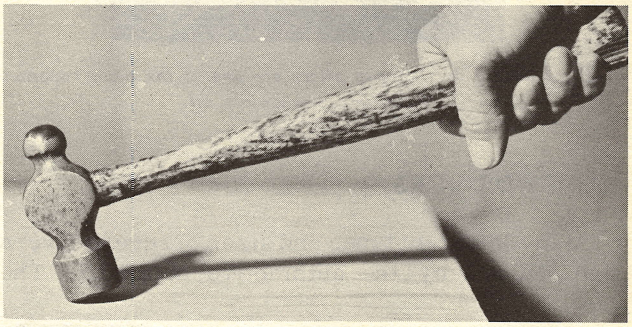
Automotive mechanics require hammers of various types and sizes. The most important is the ball peen hammer, Fig. 1-29. The flat portion of the head used for most hammering is called the face, and the other end the peen. When the peen is ball shaped it is known as a ball peen, and is used primarily for riveting work.

Ball peen hammers are usually classed according to the weight of the head without the handle. A good combination hammer set for automotive work would include 12 oz., 1/2 lb., and 4 oz. hammers. A small hammer is very handy for light work, especially when cutting gaskets out of sheet stock.



1-29. A hammer should be gripped close to the end of the handle, and the full face of the hammer should strike the work.

Simple as the hammer is, there are right and wrong ways to use it. The beginner usually has a tendency to grip the handle too close to the head. This is known as choking a hammer, and reduces the force of the blow. The hammer should be gripped close to the end of the handle, Fig. 1-29. In this way a heavier blow can be struck with less effort. Be careful not to strike the work with the edge of the hammer face, Fig. 1-30. In other words, the full face of the hammer should contact the head of the chisel or other work.



1-30. Never strike the work with the edge of the hammer face.

Never work with a hammer having a loose head. This is dangerous because the head of the hammer may fly off and cause an injury.

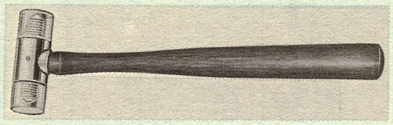
The end of the hammer handle should not be used for bumping purposes, as this will quickly split and ruin the handle. Neither should hammer handles be used as levers.

If there is any danger of damaging the surface or work, a "soft" hammer, Fig. 1-31 should be used. Such special hammers are provided with faces of rawhide, plastic or lead.

For straightening sheet metal on automotive bodies there is a large variety of hammers known as dinging hammers. These are discussed in another chapter.

CHISELS

Cold chisels, Fig. 1-32, are used for cutting metal, to cut the heads from rivets, chip metal, and to split nuts which have become rusted and cannot be loosened by means of a wrench.

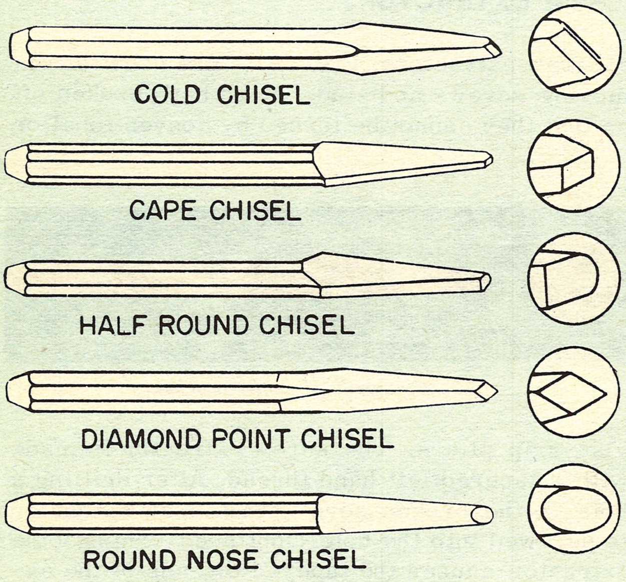


1-31. Typical soft face hammer which is used when there is any danger of damaging the work.

The cape chisel, Fig. 1-32, has a narrow cutting edge, and is used primarily for cutting keyways and narrow grooves.

In general, automotive mechanics will use only the flat chisel, and the sizes most frequently used are 3/8 in., 1/2 in. and 3/4 in.

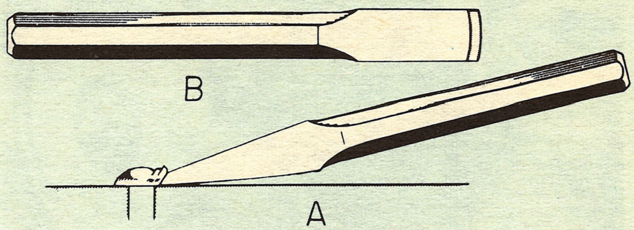
A rivet buster, Fig. 1-33, is a special form of chisel and is designed specifically for cutting the heads from rivets. It differs from the conventional cold or flat chisel, in that only one side of the cutting edge is ground.



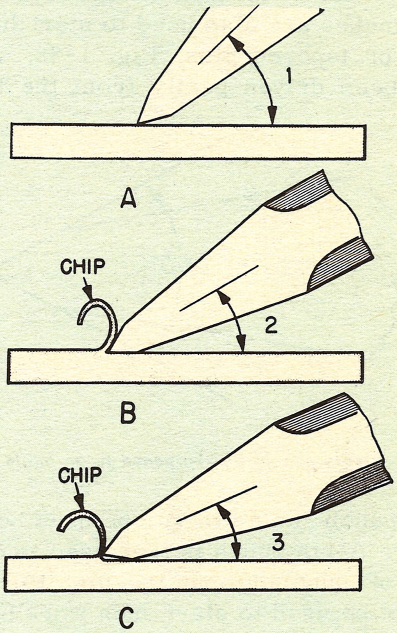
1-32. Note the cutting edge of these different types of cold chisels.

When using a chisel, a right handed person should hold the tool in his left hand, and wield the hammer with his right. The chisel should be held rather loosely with fingers curled around the chisel about one inch from the head of the chisel.

When chipping metal, the depth of the cut is controlled by the angle of the chisel, Fig. 1-34. Deeper cuts are taken as the angle of the chisel approaches the vertical. When chipping, the mechanic should keep his eye on the cutting edge, and not the head of the chisel.



1-33. A rivet buster is used to cut the heads from rivets.

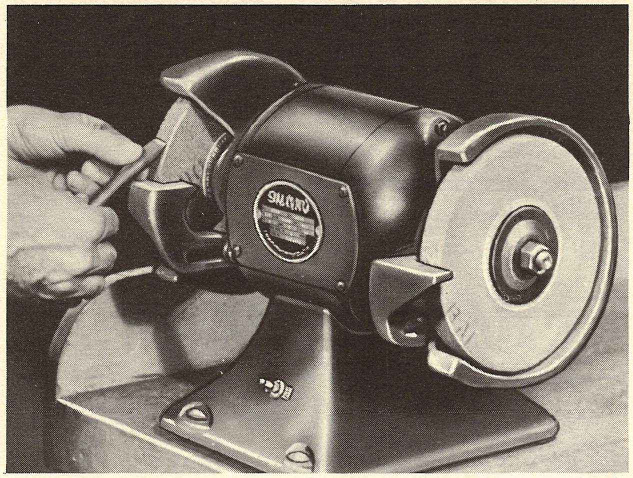


1-34. The depth of cut is controlled by the angle of the chisel.

Goggles should be worn when chipping and grinding, Fig. 1-35, and precautions should be taken so that chips will not strike anyone who is nearby. Never use a chisel on which the head has mushroomed, as portions of the "mushroom" will fly off when struck by a hammer. The battered end should be ground off on a grinding wheel.

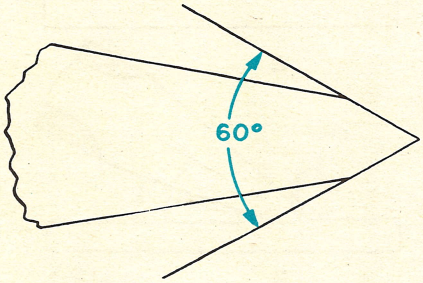
When sharpening a flat chisel, the two ground surfaces should form an angle of 60 deg., Fig. 1-36. Rivet busters and cold or cape chisels are ground on one surface only, and at an angle of approximately 30 deg.

A variety of punches, Fig. 1-37, are required in automotive work. The starting punch, or drift as it is sometimes known, is designed to punch

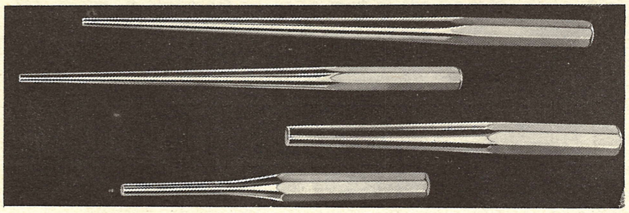


1-35. *Goggles should be worn when chipping and grinding.*

out rivets after the heads have been cut off. These punches are also used to start driving out straight or tapered pins, Fig. 1-38. After the pin has been driven partly from the hole, the starting punch can no longer be used because of its taper. A pin punch is then used to complete the job of punching out the pin. Pin punches should not be used to start such work because a hard blow on the punch would bend the slender shank.



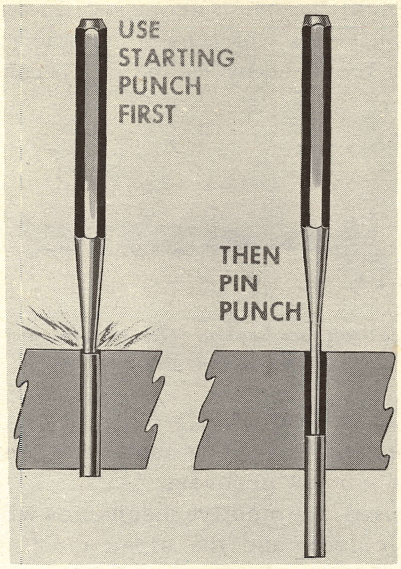
1-36. *Flat chisels should be sharpened to an angle of 60 deg.*



1-37. *A variety of punches are required in automotive service.*

A lining-up punch has a long taper, and is used to shift parts to bring corresponding holes into alignment.

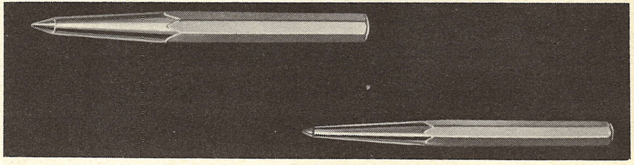
The center punch, Fig. 1-39, is ground to a fine point, and is used to mark the location of a hole that is to be drilled. Without such a mark the drill will wander over the surface and the hole will be drilled at the wrong position.



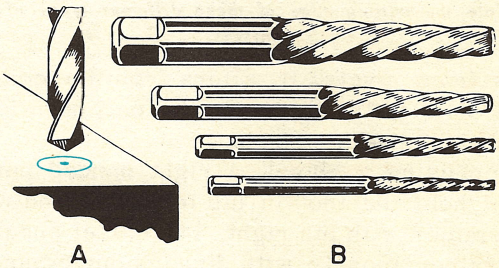
1-38. *When punching out a pin, use starting punch first and follow through with a pin punch.*

SCREW EXTRACTORS

Screw extractors, Fig. 1-40, are used for removing screws and studs which have broken off so that they cannot be turned by conventional or vise-grip pliers. The screw extractor is made with a tapered left hand thread. After drilling a hole in the broken screw, the screw extractor is screwed into the hole. Continued turning of the extractor causes the tapered threads of the extractor to jam in the hole so that the broken screw (right hand thread) can be screwed out.



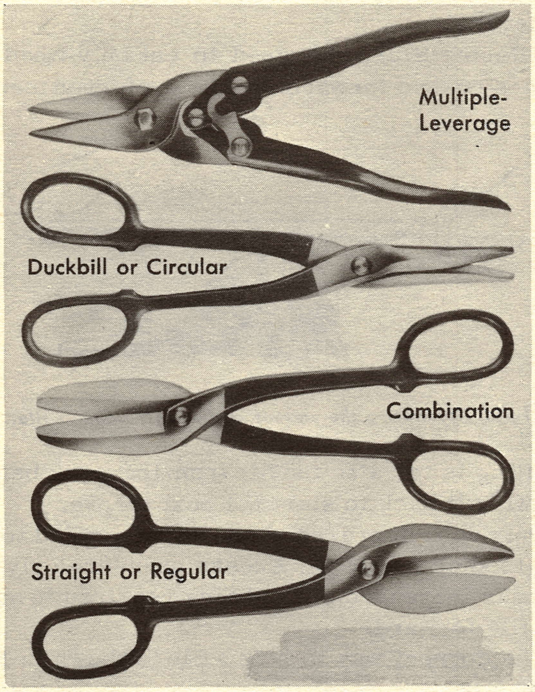
1-39. *Two types of center punches.*



1-40. *After drilling a hole in broken stud, the screw extractor is turned in, which in turn will screw out the broken stud.*

METAL SHEARS

Fot cutting sheet metal and gasket material, heavy tin shears, Fig. 1-41, are needed. The straight blade shear is the type most usually needed, however the curved blade shear and the scroll pivoter snips are also convenient to have available. The curved blade shears are used for making curved cuts, and the scroll pivoter snips to follow an irregular line easily.

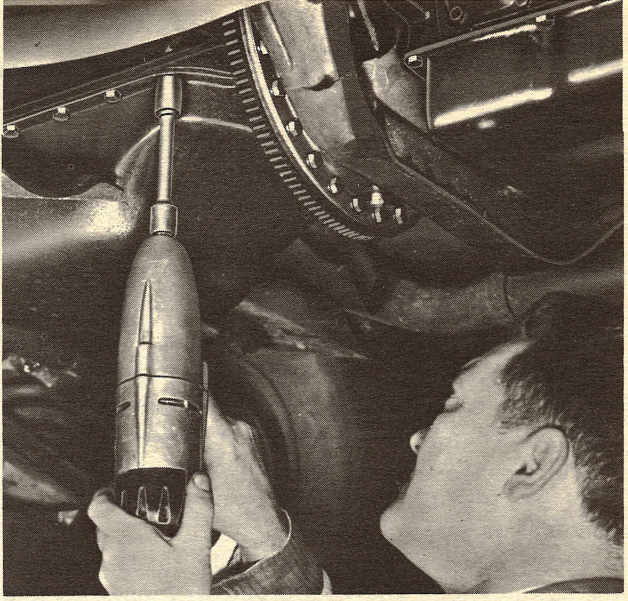


1-41. Different types of shears.

POWER WRENCHES

Power wrenches (often called impact tools), Fig. 1-42 are designed for loosening and tightening nuts, quickly. Their use results not only in a material saving of time, but also considerable reduction in fatigue on the part of the mechanic. They are designed for use with standard socket wrenches. Both electrical and pneumatic types are available.

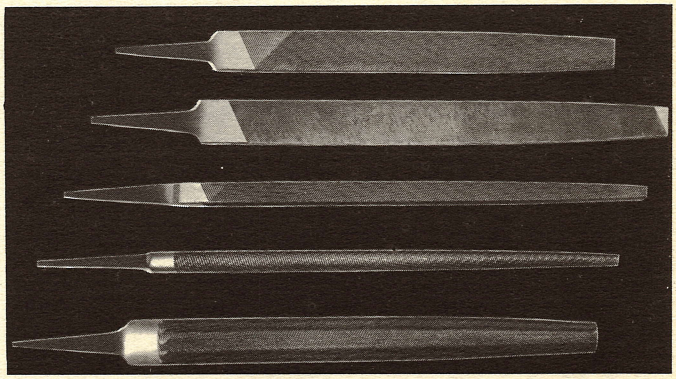
As an example of the time that can be saved by using a power wrench, a valve job on an automotive engine required 4 hr. 20 min. when conventional hand tools were used. When the same job was done with the aid of a power wrench, only 3 hr. 14 min. were required.



1-42. Power wrenches or impact tools save a lot of time and effort.

FILES

Files, Fig. 1-43, are hardened steel tools with diagonal rows of cutting edges or teeth which are used for smoothing, polishing and removing metal. There are more than 20 types of files with sizes of each type ranging from 3 to 18 in. A file with a single row of parallel teeth is called a single-cut file. Files which have one row of teeth crossing another row in a criss-cross pattern are called double-cut files, Fig. 1-43.



1-43. In order from the top: double cut mill bastard, single cut flat bastard, square, round tapered, half round.

Files are graded according to the tooth spacing. The terms used to indicate the coarseness or fineness of a file are: rough coarse, bastard, second-cut, smooth, and dead smooth. And the file may be either single cut or double cut.

There are many different shapes in which files are available, Fig. 1-43. The mill file is single-cut, tapering in thickness and width for one-third of its length. It is used primarily for fine work and is available with either square or round edges or with one safe edge. A safe edge is one without teeth.

A double-cut file, tapering in thickness and width is known as a flat file. It is used when a faster cut is desired. The hand file is single cut and similar in shape to a flat file, with parallel sides and a slight taper in thickness. It has square edges one of which is a safe edge. For rough filing, the bastard file is used.

The round file is tapered and usually single cut. In larger sizes it is also available in double cut. For enlarging large holes, a round 12 in. bastard file is usually used. If the hole is of small diameter, a round 6 in. file, usually known as a rat-tail is used. In addition to the tapered round file, there are also untapered round files available. The principal use of round files is to enlarge circular openings and file concave surfaces.

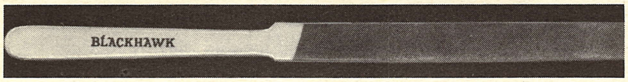
The half round file is a double cut file tapering in thickness and width, and with one flat and one oval side. It is used mainly for rough filing on concave surfaces.

The triangular file is useful for filing small notches, square or cornered holes. In addition, it is frequently used for recutting mashed and damaged threads on bolts and other parts.

As previously pointed out, files with coarse teeth are used when it is desired to remove a lot of metal as quickly as possible. Files with fine teeth remove less metal, but produce a smoother surface. In addition, the type of metal must be considered when selecting a file.

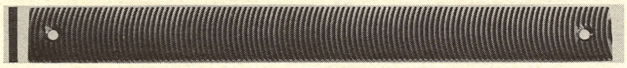
When filing cast iron, a bastard cut file should first be used and a second-cut file for finishing. On soft steel, a second-cut file is used first, and a smooth-cut for finishing. On hard steel, filing is started with a smooth-cut and finished with a dead-smooth file.

For truing ignition breaker points a file of the type shown in Fig. 1-44 is used.



1-44. Type of file used to true ignition breaker points.

On soft metals such as brass or bronze, use a bastard-cut first and then a second-cut. On aluminum, babbitt or lead, a Vixen-cut file, Fig. 1-45, similar to those used by automotive body repairmen is preferred. If that type file is not available, a bastard-cut file may be used.

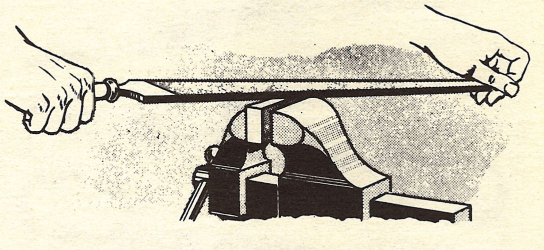


1-45. A Vixen cut file is used by auto body men and for soft metals such as lead and babbitt.

Files should never be used without a handle, as the pointed tang may be driven into the palm of the mechanic's hand, inflicting a bad wound. Whenever possible, the work to be filed should be clamped in the jaws of a vise and if the work is of soft metal, the jaws of the vise should be covered with soft caps so that the work will not be marked or otherwise damaged.

Another precaution regarding files is that they should never be used as levers. Files are brittle and will quickly break, if hammered on or used as levers.

File teeth are designed to cut only when the tool is pushed forward. So the preferred method of filing is to raise the file from the work before drawing it back to start the next stroke.

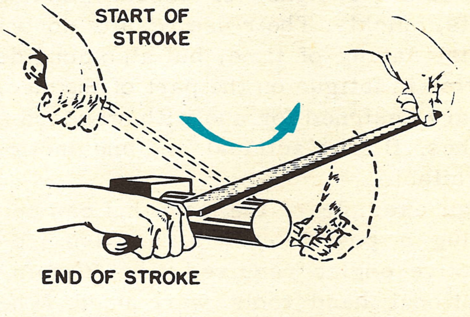


1-46. Illustrating the correct method of holding a file.

Only enough pressure should be applied to the file to keep it cutting. Excess pressure only results in increased effort being required to move the file forward.

The correct way to hold a file is shown in Fig. 1-46.

A right-handed mechanic will grasp the file handle in his right hand. The end of the file is held in the left hand with the fingers curled over the end. His feet should be spread apart and his body should lean slightly forward so that his left shoulder will tend to be over the work. In order that a flat surface is filed, the forward movement of the file must be perfectly horizontal. Any rocking of the file will result in a convex surface.



1-47. When filing a round surface, the file should be rocked.

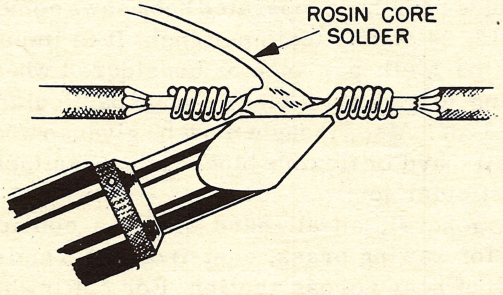
When filing a round surface, the file should be rocked as shown in Fig. 1-47.

File teeth will tend to become clogged, particularly when soft metals are being filed. As a result such material between the file teeth will tend to scratch the surface being filed. This can be overcome to a degree by first rubbing chalk on the file. To clean the teeth of a file, the teeth should be brushed with a file card or other wire bristled brush.

Files should be hung on a rack when not in use, as placing them in a drawer with other tools will quickly dull the teeth.

HOW TO SOLDER

Soldering is a method of joining two metals together. In addition, on automotive body repair work, it is used to fill dents to form a smooth surface. One of the major uses of soldering is in connecting electric wires to instruments, and other electrical equipment. This keeps the wires from becoming loose or disconnected, as the result of vibration.



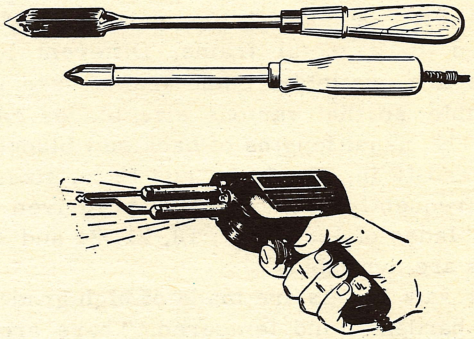
1-48. *Method of soldering splice in electric wires.*

Solder is an alloy of lead and tin. By varying the proportions of the lead and tin, solder of different melting points can be secured. Solders that melt readily are known as soft solder, while those which require greater heat are known as hard solder.

The process of soldering consists of first cleaning the surfaces to be soldered. The joint is then heated and a flux is applied. The flux is a chemical designed to keep oxides from forming, and permit the solder to adhere to the surfaces. After the flux is applied, the solder is then melted into the joint, Fig. 1-48. This can be done by means of a soldering copper or the flame of a torch.

Soldering coppers, Fig. 1-49, often called soldering irons, are used mostly for soldering small pieces and when there is danger of an open flame damaging nearby parts. Made of copper, the tips of these tools must be given a coating of solder before they are used, Fig. 1-50. This is known as tinning, and the process is to first file the tip of the copper so that it is clean and smooth. It is then heated, dipped in flux and solder applied. Some mechanics prefer to melt the solder on the surface of a building brick, and then rub the tip of the copper on the solder. Another method is to use a block of sal ammonia.

After the iron has been tinned, the mechanic should take care that it is not overheated. That would burn the copper and it would be necessary to re-tin it.

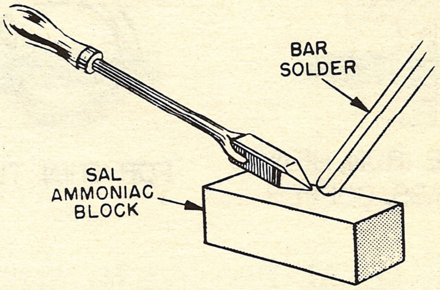


1-49. *Different sizes of soldering coppers are needed. Electric coppers are shown at the bottom.*

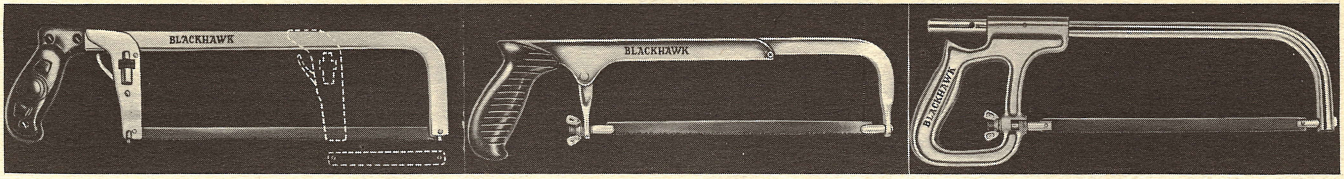
On some soldering jobs, it is desirable to first tin the surfaces to be joined, and then solder them together. That process is usually followed on larger areas where a strong joint is to be made. It is also used when solder is to be applied to sheet iron.

Soldering coppers may be heated in a flame or special oven. Or soldering irons with electric heating elements may be used, Fig. 1-49.

There are many different types of fluxes available. It is important to select the type best suited for the metals to be joined. For electrical connections a rosin type flux is recommended. An acid type flux is used when soldering sheet iron.



1-50. *One method of tinning a soldering copper.*

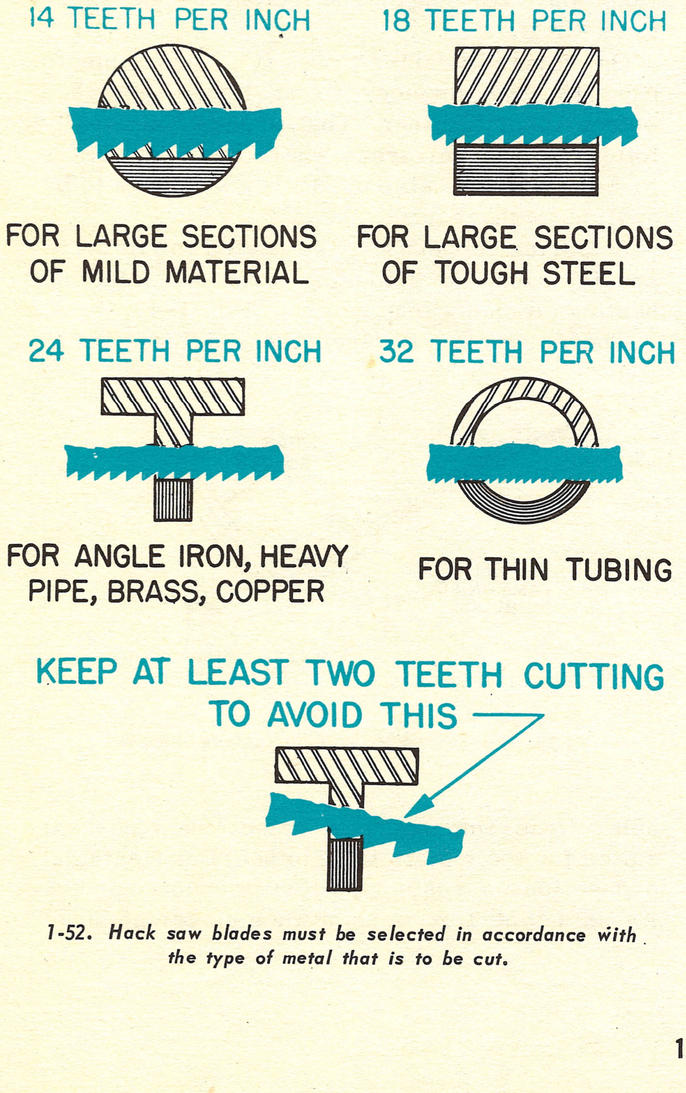


1-51. Different types of adjustable hack saw frames.

HOW TO USE A HACK SAW

Hack saws are used to cut metal. As shown in Fig. 1-51, the detachable cutting blade is mounted in a metal frame. Different length frames are available. Some frames are made adjustable so that various size blades can be used. The usual lengths of hack saw blades are 8, 10, and 12 in. The 10 in. and 12 in. sizes are most frequently used. For power-driven hack saws, blades of 12, 14, 17, 18, 21, 24 and 30 in. lengths are available.

Hack saw blades are made of high grade tool steel, hardened and tempered. There are two types, the all-hard and the flexible. All-hard blades are hardened throughout, while only the teeth of flexible blades are hardened. So that the blades can be attached to the frame, the blades are provided with holes at both ends. These holes are then slipped on the pins on the frame. To adjust the tension of the blade, and also to secure it tightly to the frame, the position of one of the pins is adjustable. This adjustment is made by either a wing nut or by turning the handle.


14 TEETH PER INCH
FOR LARGE SECTIONS OF MILD MATERIAL
18 TEETH PER INCH
FOR LARGE SECTIONS OF TOUGH STEEL
24 TEETH PER INCH
FOR ANGLE IRON, HEAVY PIPE, BRASS, COPPER
32 TEETH PER INCH
FOR THIN TUBING
KEEP AT LEAST TWO TEETH CUTTING TO AVOID THIS

1-52. Hack saw blades must be selected in accordance with the type of metal that is to be cut.

The "set" in a saw refers to the amount the teeth are pushed out in opposite directions from the sides of the blade. The teeth of all hack saw blades are set to provide clearance for the blade. The usual types of set are alternate, raker and undulated. In addition, there is a double alternate set.

Blades for hand-operated hack saws come with 14, 18, 24 and 32 teeth per inch. It is important that the teeth per inch be considered when selecting a hack saw blade for a particular job, Fig. 1-52. Also, thought must be given to whether the all-hard or flexible blade is more suitable for a particular job.

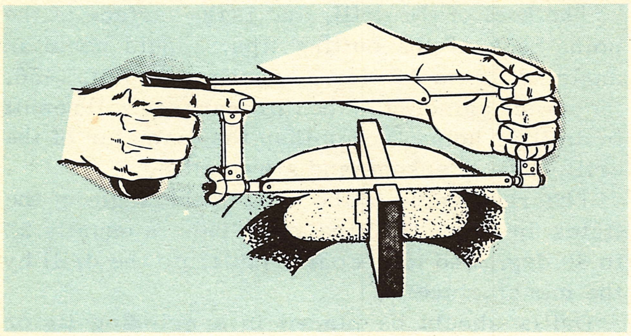
In general, an all-hard blade is considered best for sawing brass, cast-iron, steel and other stock of heavy cross section. For cutting hollow shapes, and metals of light section such as channel iron, tubing tin, copper, aluminum or babbitt, a flexible blade is preferable.

Hack saw blade manufacturers recommend that 14-tooth saws be used for cutting soft steel, brass, cast-iron and stock of heavy cross section. For cutting drill rod, light angles, high speed steel, tool steel and small solids, 18-tooth blades are recommended. Use 24-tooth blades for cutting brass tubing, heavy B-X cable, iron pipe, metal conduit and drill rod. For cutting thin tubing, sheet metal, light B-X cable, channels, etc., 32-tooth blades are suggested.

After selecting the correct blade for the material, it is placed on the pins on the hack saw frame, with the teeth pointing toward the front of the frame. The blade is then stretched tightly in the frame.

If an accurate cut is to be made, it is advisable to mark the stock with a scriber, and nick the work with a file. The nick will make it easier for the saw to start cutting and also insure accuracy. Make sure the work is held securely in a vise, with the line to be cut as close to the vise jaws as possible. Use sufficient pressure on the saw when starting the cut, so that the saw teeth immediately begin to bite into the metal. The hack saw blade should be held vertically and moved forward with a light steady stroke. At the end of the forward stroke, relieve the pressure and draw the saw straight back. See Fig. 1-53.

The most effective cutting speed is about one stroke per second. When the material is nearly cut through, the pressure on the blade should be reduced to prevent the teeth from catching. When cutting thin stock, it is advisable to clamp it between two pieces of wood or soft metal, and saw through all three pieces. This will prevent the saw from sticking, and also prevent possible damage to the work.

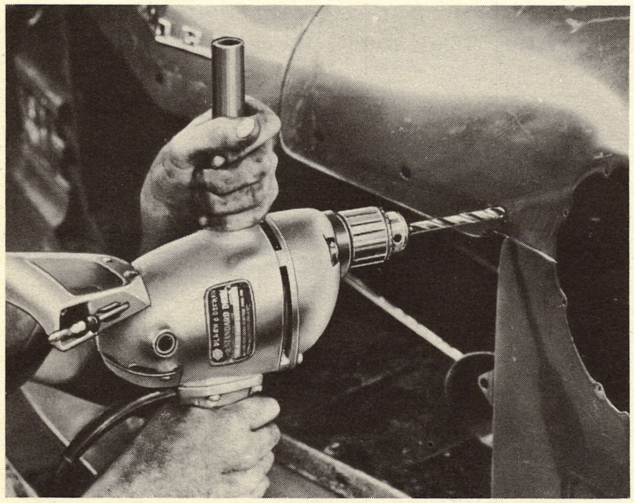


1.53. Illustrating the correct method of using a hack saw.

For cutting round holes in metal, a circular saw is advisable. The circular saw is driven by an electric drill, and is used for drilling large diameter holes in instrument panels and fire walls, for the installation of instruments and other accessories. It is provided with a centering or pilot drill for starting and centering the cut.

DRILLING, REAMING AND TAPPING

The automotive mechanic frequently finds it necessary to drill holes in order to install additional accessories and equipment on various types of automotive vehicles, such as passenger cars, trucks and tractors.



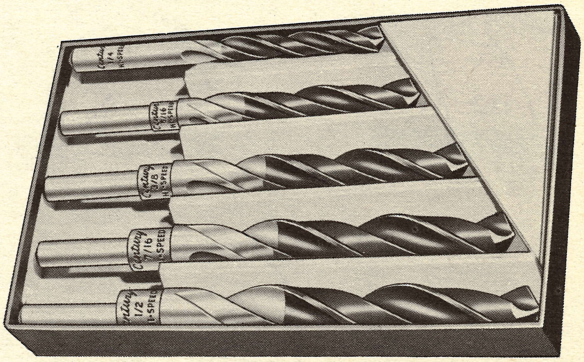
1-54. Electric drills have many uses and are a "must" for every mechanic's tool kit.

While holes are occasionally drilled with a hand or breast drill, the usual method is to use an electric drill, Fig. 1-54. The electric drills used in most automotive shops are 1/4 in., 1/2 in., and 3/4 in. The size designations indicate the largest size drill that should be inserted in the chuck. If drills larger than the specified size are used, the electric drill will be overloaded and will overheat. Premature failure can then be expected. It should be pointed out, however, that a well-made electric drill can stand a certain degree of overload for a short period without harm.

TWIST DRILLS

The tool used to do the actual cutting is known as a twist drill, Fig. 1-55. A twist drill has two cutting edges.

Twist drills are made of either carbon steel, or high speed steel. However, the former quickly becomes dull and if heated excessively, it will lose its hardness. High speed steel will retain its temper when red hot and twist drills of that material are therefore preferred.



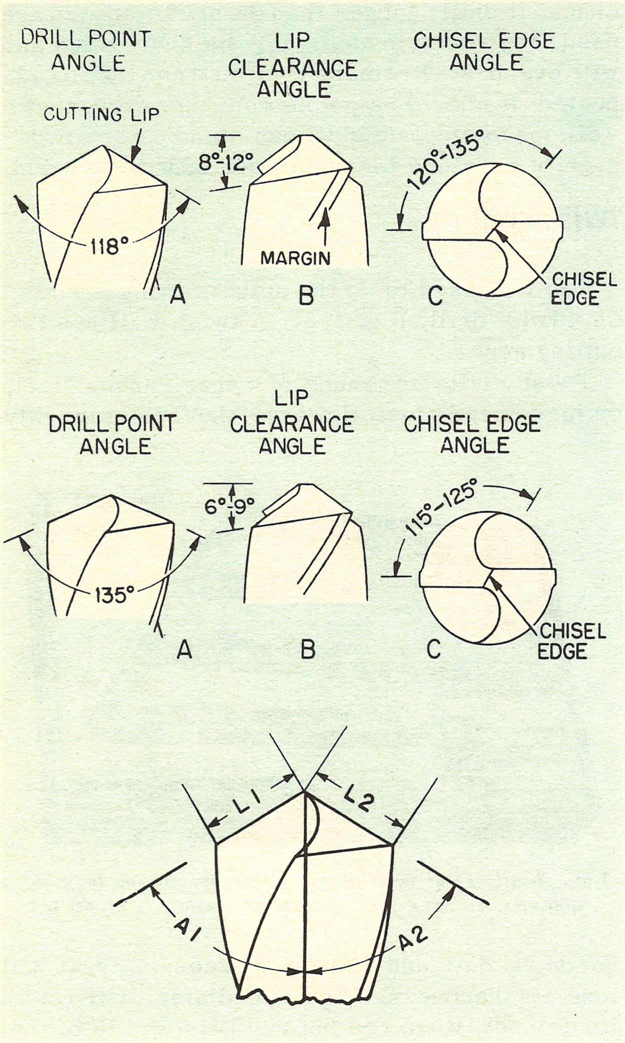
1-55. Small set of twist drills. These, ranging up to ½ in. diameter, all have ¼ in. shanks for use in a ¼ in. drill.

While there are other types of drills, the straight shank drill is used almost entirely in automotive maintenance shops.

SHARPENING DRILLS

Before a drill is used, it is important that it be correctly ground and sharpened. Unless the drill is in good condition it may drill an oversize hole, possibly break or at least cut slowly.

A correctly sharpened drill will have: (1) equal and correctly sized drill point angles, (2) equal length cutting lips, (3) correct clearance behind the cutting lips, and (4) correct chisel edge angle. All four are equally important and are illustrated in Fig. 1-56. For general drilling, the angles shown in the upper part of Fig. 1-56 are used, while if very hard and tough materials are to be drilled the angles shown in the center of the illustration are used. The lower portion of the illustration shows what is meant by the two halves, A-1 and A-2 of the drill point angle, as well as the two equal-length cutting lips, L-1 and L-2.



1-56. Indicating the various angles on a twist drill.

Lip clearance behind the cutting lip at the margin is determined by inspection, while the cutting edge or lip is measured by a gauge. The lip clearance angle may be within certain limits, as shown in Fig. 1-56, but must be the same on both sides of the drill. The margin, shown at the top of Fig. 1-56, is the narrow strip which extends the entire length of the flutes, and is practically the full diameter of the drill. The portion back of the margin is slightly less in diameter and is the body clearance.

Both lips of a twist drill must be the same length. For most materials they should be ground to an angle of 59 deg. If the cutting edges are ground at different angles, and the point is in the center, only one lip will cut. The angle of 59 deg. for the lip is correct when the drill is to be used on aluminum, steel and cast-iron. For brass and copper the angle should be 50 deg.; while 45 deg. is preferred for Bakelite, plastic, wood or fibre.

The heel of the drill, that is the surface of the point back of the cutting lips, should be at an angle of 12 to 15 deg., as shown in Fig. 1-56. Incorrect grinding of the lip clearance will result in drilling holes larger than the diameter of the drill, drill breakage and slow cutting.

The rake angle of the drill is the angle of the flutes in relation to the axis. This is usually 22 to 30 deg., and is of course built into the drill by the manufacturers.

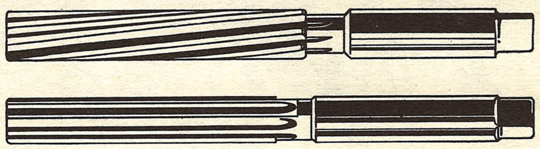
Drills should be placed in a grinding jig or attachment for sharpening. This will insure accuracy.

REAMERS

When it is desired to have a hole with particularly smooth surface or have the hole finished to an exact diameter, a reamer, Fig. 1-57, should be used. The hole is first drilled to a diameter slightly smaller than the desired finished size, and then finished with the reamer.

A reamer consists of three parts, the body, shank and cutting blades. The reamer can be rotated by hand, and a suitable wrench or handle; or it can be power driven. When power driven, the speed is approximately 50 rpm.

The blades of a reamer are made of steel, and hardened to such an extent that they are extremely brittle. They must, therefore, be carefully handled. The usual method of storing reamers is to provide a wooden rack with a separate division for each reamer.



1-57. The upper view is of a spiral flute reamer, while the lower is a straight flute reamer.

When reaming a hole, the reamer should be turned in the cutting direction only. Also only a very little metal should be removed by the reamer, as it is a finishing operation and it is not designed to make heavy cuts. Usually .002 in. is the limit of the amount of metal to be removed by reaming.

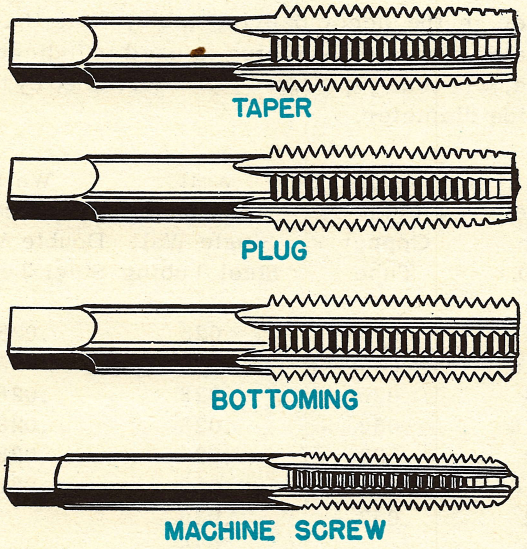
By steady even rotation of the reamer, "shattering" is reduced or eliminated.

In Fig. 1-57 are shown two solid reamers, a spiral flute reamer, and a straight flute reamer. The spiral flute is more expensive but has a reduced tendency toward chattering. Reamers of the types shown in Fig. 1-57 are available in standard sizes and are also available in size variations of .001 in. for special work.

Where only occasional reaming is to be done, some shops will secure several expansion or adjustable reamers, embracing the required range of sizes. Care must of course be taken when adjusting the size of the reamer, to be sure it is correctly set. In setting adjustable reamers, the usual method is to use a micrometer.

Expansion reamers are usually available in standard sizes from 1/4 in. to 1 in. by 32nds. They are designed to allow the blades to expand 1/32 in. For example, the 1/4 in. expansion reamers will cover sizes ranging from 1/4 in. to 9/32 in.

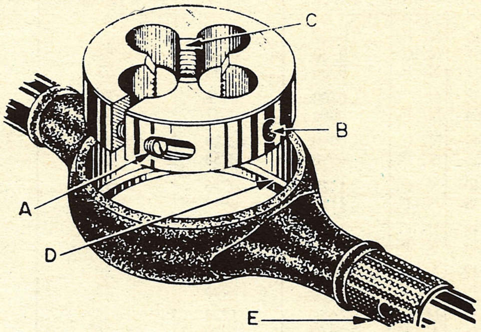
In automotive service work, reamers are used for fitting such parts as king pins and piston pins. However, a power-driven hone is now used extensively for fitting piston pins.



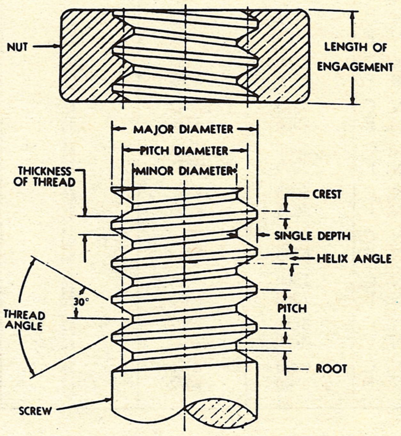
1-58. Illustrating four different types of taps.

TAPS AND DIES

Taps, Fig. 1-58, and dies, Fig. 1-59, are thread-cutting tools. A tap is used to cut internal threads on such parts as nuts, while a die cuts external threads on bolts and studs. As shown on page 1-26 there are many different types of bolts and nuts.



1-59. An adjustable round split die for cutting external threads. A- adjusting screw, B- drive hole, C- cutting teeth, D- shoulder for die, E- die holder handle.



1-60. Illustrating terms used in describing American Standard screw threads.

There is special terminology used when discussing threads, bolts and nuts, Fig. 1-60, and, to avoid confusion, it is important that such terms be understood.

The major diameter, formerly known as the outside diameter, is the largest diameter of the thread. The minor diameter is the diameter taken at the base of the thread. The pitch of a thread is the distance measured parallel to its axis, between corresponding points on adjacent thread forms, in the same axial plane and on the same side of the axis. The number of threads per inch is the reciprocal of the pitch in inches.

When it is desired to drill and tap a hole, it is necessary that the hole be of the correct diameter for the particular tap. That is known as the tap drill. The different tap and drill sizes are given in Fig. 1-61.

When it is desired to drill a hole into which a bolt is to be inserted, the drill is known as a clearance or body drill.

Nominal size	Thr'd series	Major diameter, inches	Root diameter, inches	Tap drill to produce approx. 75% full thread	Decimal equivalent of tap drill
0–80	N. F.	.0600	.0438	3/64	.0469
1–64	N. C.	.0730	.0527	53	.0595
72	N. F.	.0730	.0550	53	.0595
2–56	N. C.	.0860	.0628	50	.0700
64	N. F.	.0860	.0657	50	.0700
3–48	N. C.	.0990	.0719	47	.0785
56	N. F.	.0990	.0758	45	.0820
4–40	N. C.	.1120	.0795	43	.0890
48	N. F.	.1120	.0849	42	.0935
5–40	N. C.	.1250	.0925	38	.1015
44	N. F.	.1250	.0955	37	.1040
6–32	N. C.	.1380	.0974	36	.1065
40	N. F.	.1380	.1055	33	.1130
8–32	N. C.	.1640	.1234	29	.1360
36	N. F.	.1640	.1279	29	.1360
10–24	N. C.	.1900	.1359	25	.1495
32	N. F.	.1900	.1494	21	.1590
12–24	N. C.	.2160	.1619	16	.1770
28	N. F.	.2160	.1696	14	.1820
¼–20	N. C.	.2500	.1850	7	.2010
28	N. F.	.2500	.2036	3	.2130
5/16–18	N. C.	.3125	.2403	F	.2570
24	N. F.	.3125	.2584	I	.2720
⅜–16	N. C.	.3750	.2938	5/16	.3125
24	N. F.	.3750	.3209	Q	.3320
7/16–14	N. C.	.4375	.3447	U	.3680
20	N. F.	.4375	.3726	25/64	.3906
½–13	N. C.	.5000	.4001	27/64	.4219
20	N. F.	.5000	.4351	29/64	.4531
9/16–12	N. C.	.5625	.4542	31/64	.4844
18	N. F.	.5625	.4903	33/64	.5156
⅝–11	N. C.	.6250	.5069	17/32	.5312
18	N. F.	.6250	.5528	37/64	.5781
¾–10	N. C.	.7500	.6201	21/32	.6562
16	N. F.	.7500	.6688	11/16	.6875
⅞– 9	N. C.	.8750	.7307	49/64	.7656
14	N. F.	.8750	.7822	13/16	.8125
1– 8	N. C.	1.0000	8376	⅞	.8750
14	N. F.	1.0000	9072	15/16	.9375

1-61. Table of thread sizes, together with tap drill and clearance drill sizes.

Taps and dies are marked according to the type and diameter thread they will cut. For example, an 8-32 is designed to cut 32 threads per inch on No. 8 stock.

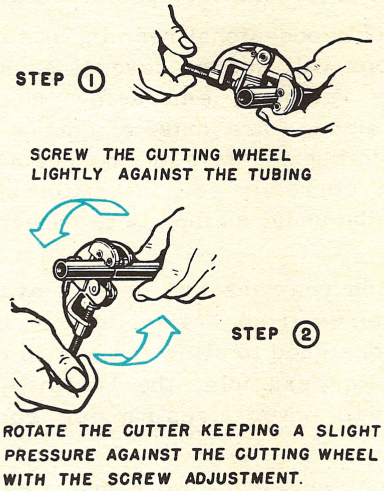
When tapping a hole with a tap or cutting a thread with a die, considerable care is required. Taps are easily broken. When using a tap or die, it is important that the direction the tool is turned be reversed frequently. This is done to free the tool of chips and also recut the threads. Forcing the tool will result in tool breakage, ruined parts and poor threads.

When threading steel parts a lubricant such as lard oil should be used. Kerosene is preferred for use with aluminum. No lubricant is required for threading brass or cast iron.

FABRICATING TUBING

Tubing is used extensively in automobiles, trucks and tractors for oil, fuel and brake lines. Great care must be exercised in fitting tubing for specific jobs. Carelessness in fabrication, or the selection of the wrong material, may result in accidents and harm to the occupants of the vehicle.

Soft copper tubing is usually considered satisfactory for gasoline lines. However, it should never be used for hydraulic brake lines as it is not strong enough to withstand the pressures developed in such lines. For hydraulic brake lines only special tubing designed for the purpose should be used. Such tubing is of seamless steel.

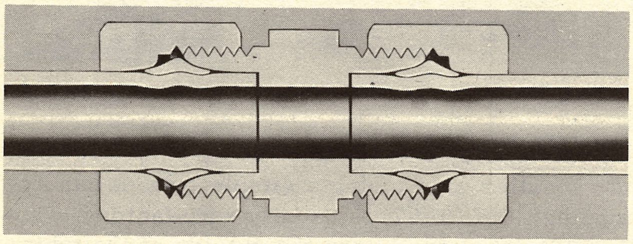

STEP ①
SCREW THE CUTTING WHEEL LIGHTLY AGAINST THE TUBING
STEP ②
ROTATE THE CUTTER KEEPING A SLIGHT PRESSURE AGAINST THE CUTTING WHEEL WITH THE SCREW ADJUSTMENT.

1-62. Showing the procedure for cutting copper tubing with a special cutter.

Dimensions of copper and steel tubing are given in the accompanying table. Note that the outside diameter of tubing is used to indicate its size, whereas pipe sizes are determined by their inside diameter.

Size or O.D.	Wall Thickness Copper Tube	Wall Thickness Single Wall Steel Tubing	Wall Thickness Double Wall Steel Tubing
1/8	.030	.025	.025
3/16	.030	.025	.025
1/4	.030	.028	.028
5/16	.032	.028	.028
3/8	.032	.028	.028
7/16		.030	.032
1/2	.032	.030	
1/2		.035	
9/16		.030	
5/8	.035	.035	.035

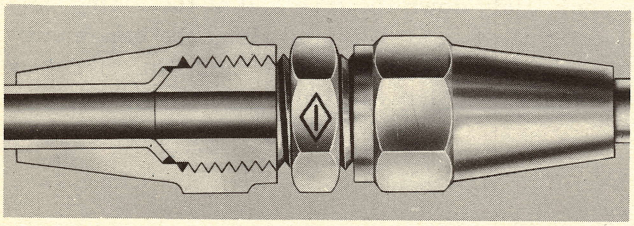
When making a line of tubing the first step, after selecting the size and material of which the line is to be made, is to cut it to the length desired, Fig. 1-62. In cutting tubing only a special tubing cutter should be used, as it is imperative that the tubing be cut smoothly and at right angles to the center line of the tubing. Unless the end of the tubing is smooth, and at right angles to the center line of the tubing, it will be impossible to make a leak-proof joint. Tubing can be connected to equipment by either flare-type or flareless-type fittings. The latter type, Fig. 1-63, is known as a compression fitting, and requires only that the end of the tubing be smooth and true. The connection can be quickly made, but has the disadvantage that it cannot be taken apart many times without the probability of leaks occurring.



1-63. Flareless type tubing connector.

The flare-type connection, Fig. 1-64, as the name implies, requires that the end of the tubing be flared, Fig. 1-65. This type of fitting can be disassembled many times with but little possibility of leaks occurring.

A tube cutting tool is shown in Fig. 1-62. Such a tool will make a clean cut, square with the sides of the tubing. In addition, there is no possibility of filings getting into the tubing, and subsequently causing trouble in the system.



1-64. Note how end of tubing is flared for this flare-type tubing connector.

With a tubing cutter the position of the cutting wheel is adjusted until it contacts the surface lightly. The complete tool is then swung completely around the tubing, after which the cutting wheel is again adjusted. The procedure is repeated until the cut is completed.

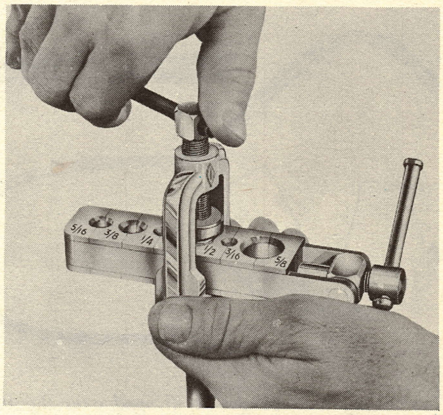
After the tubing has been cut to the desired length, the ends should be reamed or burred to remove any burrs at the end of the tubing. One method of doing this is to use the reamer provided on one end of the tubing cutter. When reaming tubing, it is always important to hold the end of the tubing pointed down, so metal chips will not drop into the tubing.

One type of reaming tool is an "inner and outer" reamer. This is a cylindrically shaped tool that reams both the inside and outside edges of the tubing.

With the tubing cleanly and squarely cut, reamed and with burrs removed, it is then ready for either a tight joint with a compression (flareless) type fitting, Fig. 1-63, or for flaring for use with a flared-type fitting, Fig. 1-64.

FLARING

There are several different types of flaring tools available. One type consists of a flaring bar and screw feed flaring yoke, Fig. 1-65.



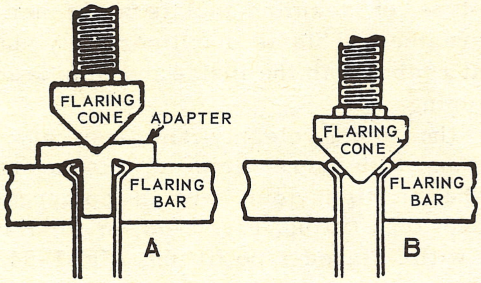
1-65. Using a flaring tool on a piece of copper tubing.

When making a flare with a tool of this type, the tubing is placed in the flaring bar with the end protruding slightly above the face of the bar. Care must be taken that the tubing is clamped in the bar, so pressure of the flaring cone will not force the tubing through the bar.

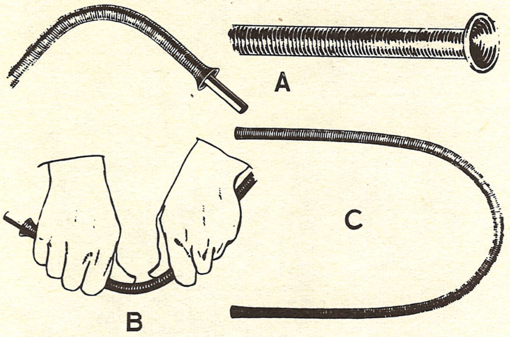
Before slipping the yoke over the bar to start flaring, a little oil should be placed on the cone or spreader. Particular care must be taken when the flared connection is to be used on units subject to vibration. It is not wise to work the tubing any more than is necessary, because the working will tend to make the metal hard and brittle so it is more subject to breakage.

On tubes flared too short, the full clamping area of the fitting is not used and consequently the joint may leak or suffer early failure. Tubing flared too long will stick and jam on the threads during assembly. Flares that are not straight usually result from the fact that the tubing was cut on an angle.

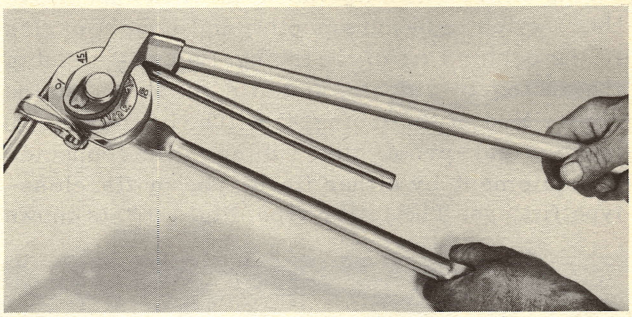
Brazed steel tubing, such as is used for hydraulic brake lines, must be double flared. If only single flared, it will invariably crack or split. Double flaring is similar to single flaring except that an additional operation is introduced. To make a double flare with the tool shown in Fig. 1-66, two operations are involved. In the first operation, the tubing is belled through the use of an adapter. In the second operation, the adapter is removed and the flaring cone screwed down. This folds the tubing down on itself and forms an accurate 45 deg. double flare without cracking or splitting the tubing.



1-66. Procedure for making a double flare in tubing.



1-67. This spring type bender is slipped over the tubing so that the tubing can be bent without kinking.



1-68. For larger size tubing a mechanical bender is required.

It is frequently necessary to bend tubing. This should be done only with special tube benders. Only soft temper tubing should be bent. On smaller size tubing a simple outside bending spring, Fig. 1-67, is usually satisfactory. This bender is slipped over the outside of the tubing and prevents the tubing from kinking when it is bent. When using a spring-type tube bender, it must be remembered that the tubing must be bent somewhat further than required, and then backed up to the desired angle. In that way the spring is loosened in the bender and can be easily removed.

On larger sizes of tubing or where precise and uniform bends are required, the use of a lever type or gear type bender, Fig. 1-68, should be used. These benders can be slipped on the tubing at the exact point the bend is desired, and are particularly advantageous when the tubing has been partly connected, or is located in hard-to-get-at places. Bulk tubing is sold in coils. When removing a piece of copper tubing from a coil, first place the coil on the bench. Hold down the free end of the tubing, and then roll the coil of tubing along the bench until the desired length is obtained. In this way kinking the tubing will be avoided.

QUIZ - AUTOMOTIVE TOOLS

Write answers on a separate sheet of paper. Do not write in this book.

1-The size of open end wrenches increase in:
  a. 1/16 in. steps
  b. 1/32 in. steps
  c. 1/8 in. steps
  d. 1/4 in. steps

2-What is the main reason for using a box type wrench?
  a. Greater strength
  b. Used on rounded nuts
  c. Less liable to slip from nut

3-List the three standard size drives for socket wrenches.

4-Why are torque wrenches needed?

5-A Stillson wrench is used to tighten:
  a. Square nuts
  b. Hexagon nuts
  c. Pipe connections

6-The channel-lock plier is designed to:
  a. Lock channels
  b. Have adjustable openings of different sizes and at the same time have the jaws remain parallel

7-The end of a Phillips type screwdriver is:
  a. A flat blade
  b. Pointed end with four grooves
  c. Fluted end

8-A set screw wrench has:
  a. Four sides
  b. Six sides
  c. Eight sides

9-The rounded end of a machinists hammer is known as the:
  a. Face
  b. Peen
  c. Riveter

10-A cape chisel is used to cut:
  a. Narrow grooves
  b. Rivet heads
  c. Tool steel

11-When using a chisel it should be held:
  a. Tightly in the hand
  b. With a pair of slip joint pliers
  c. Loosely in the hand

12-A screw extractor has:
  a. Tapered right hand threads
  b. Tapered left hand threads

13-A file with a single row of parallel teeth is called:
  a. A bastard file
  b. A singleton file
  c. A single cut file

14-A file with one row of teeth crossing the other is called:
  a. A criss-cross file
  b. A double-cut file
  c. A Vixen-cut file

15-When filing soft steel, which type file should be used first:
  a. A bastard file
  b. A smooth-cut file
  c. A second-cut file

16-Solder is an alloy of:
  a. Lead and tin
  b. Lead and zinc
  c. Tin and zinc
  d. Lead and cadmium

17-Hack saw blades are made of:
  a. High grade tool steel
  b. Chilled cast iron
  c. Carbaloy

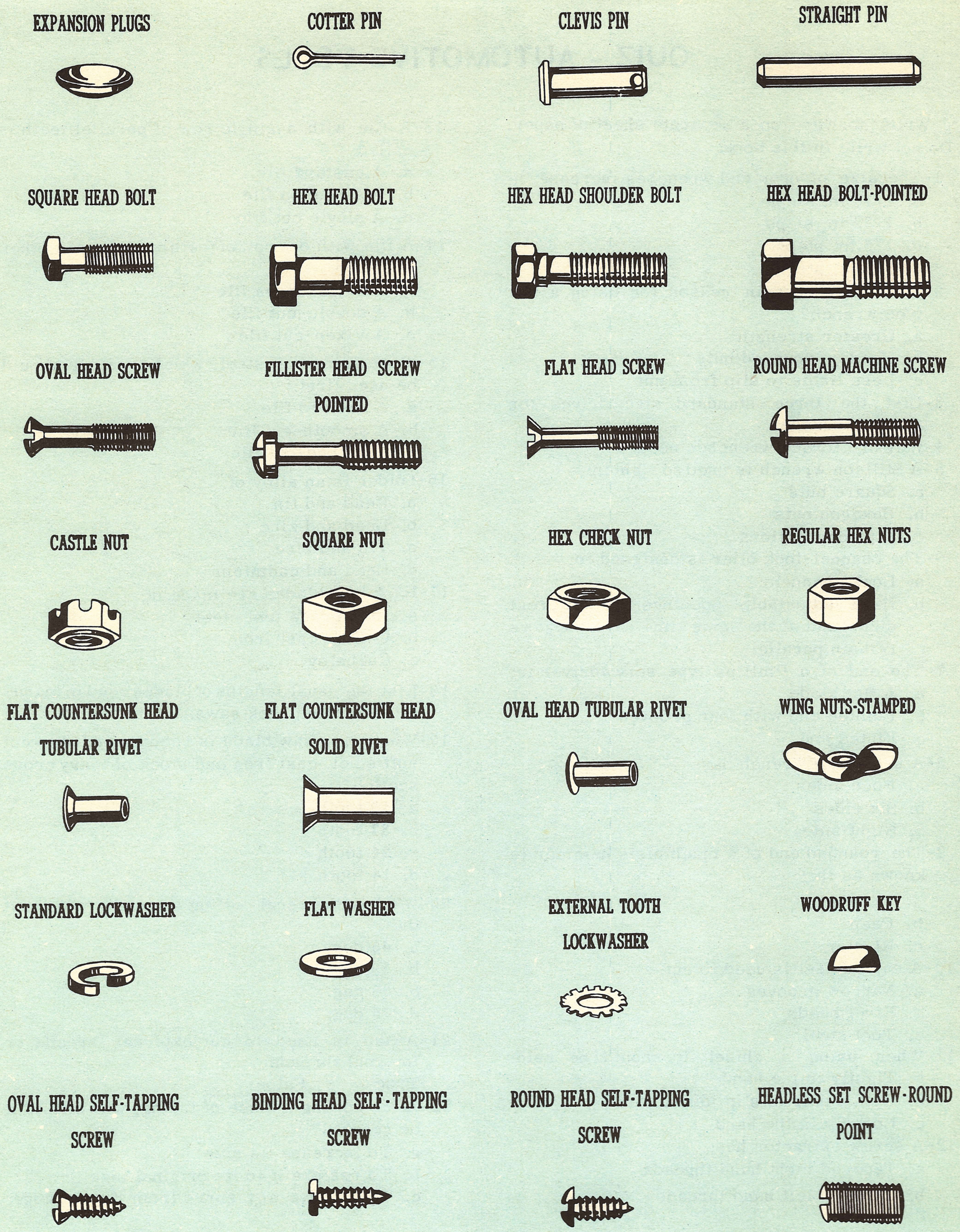
18-List the usual lengths of blades used in manually operated hack saws.

19-What tooth saw blade is recommended to cut soft steel, cast iron and stock of heavy cross section?
  a. 16 tooth
  b. 32 tooth
  c. 24 tooth
  d. 14 tooth

20-What is the usual cutting lip angle on a twist drill?
  a. 45 deg.
  b. 59 deg.
  c. 60 deg.
  d. 75 deg.

21-A tap is used to cut external threads or internal threads.
  True_____, False_____

22-After cutting a piece of tubing, why should it be reamed?
  a. To increase its size
  b. To restore it to its original size
  c. To remove any burrs from the cut edge.


EXPANSION PLUGS
COTTER PIN
CLEVIS PIN
STRAIGHT PIN
SQUARE HEAD BOLT
HEX HEAD BOLT
HEX HEAD SHOULDER BOLT
HEX HEAD BOLT-POINTED
OVAL HEAD SCREW
FILLISTER HEAD SCREW POINTED
FLAT HEAD SCREW
ROUND HEAD MACHINE SCREW
CASTLE NUT
SQUARE NUT
HEX CHECK NUT
REGULAR HEX NUTS
FLAT COUNTERSUNK HEAD TUBULAR RIVET
FLAT COUNTERSUNK HEAD SOLID RIVET
OVAL HEAD TUBULAR RIVET
WING NUTS-STAMPED
STANDARD LOCKWASHER
FLAT WASHER
EXTERNAL TOOTH LOCKWASHER
WOODRUFF KEY
OVAL HEAD SELF-TAPPING SCREW
BINDING HEAD SELF-TAPPING SCREW
ROUND HEAD SELF-TAPPING SCREW
HEADLESS SET SCREW-ROUND POINT

2-1. Illustrating fasteners used on automobiles.

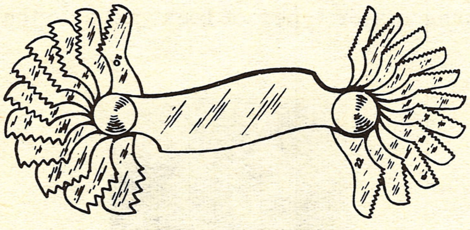
FASTENING DEVICES

There are many different devices used for fastening different parts together in the modern automobile. These devices range all the way from the familiar bolt and nut to spring clips, and sheet metal screws.

A number of the different fastening devices are illustrated in Fig. 2-1. It is important to know the difference between and to be able to identify these various types of fastening devices.

The term machine screw is applied to that type of threaded screw which is turned into threaded holes in metal parts.

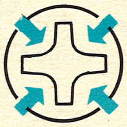
Bolts require nuts, and the bolts are inserted through holes in parts so that the threaded end of the bolt protrudes. The nut is then turned on the exposed end of the bolt.



2-2. Type of gauge used for measuring the pitch of threads.

Both ends of a stud are threaded, one end is screwed into a threaded hole of a part such as an engine cylinder. After another part with a suitable hole is placed in position on the stud, a nut is placed on the exposed end of the stud and tightened. And in that way the parts are held together.

Threads on bolts are known as external threads, while threads in nuts are known as internal threads. The major terms used in connection with threads include major diameter, minor diameter, pitch, pitch diameter and lead, Fig. 1-60. The major diameter is the largest diameter of the thread on the screw. The minor diameter is the smallest diameter of the thread or screw. The pitch is the distance from a given point on a thread, to the corresponding point on the next thread, and is measured parallel to the axis of the screw. The pitch diameter is that of an imaginary cylinder, the surface of which would pass through the threads at such point as to make equal the width of the threads, and the width of the spaces cut by the cylinder.



2-3. Character of opening in head of Phillips screw.

Bolts and screws are usually designated by their length, major diameter, and by the number of threads per inch. In Fig. 1-61, the threads of various types and sizes as listed in the Society of Automotive Engineers Handbook are given. It will be noted that sizes more than 1/4 in. are designated by number, and from 1/4 in. and above, they are designated in fractions of an inch.

In order to measure the pitch of a thread, a special gauge such as shown in Fig. 2-2 should be used.

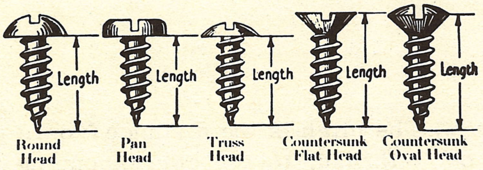
As pointed out previously, one method of designating screws and bolts is by the type of head. Most bolts have hexagonal heads, while machine screws will have heads ranging from the conventional hexagon to straight slots, and are installed by means of a screw driver. In addition, some screws will have special recesses requiring special tools for their installation. These special recesses include the Phillips, Fig. 2-3, fluted and the internal hexagon or Allen type.

One special type of screw is known as a sheet metal or self-tapping screw, Fig. 2-4. Because of its fluted and tapered point it will cut its own threads as it is screwed into the sheet metal.

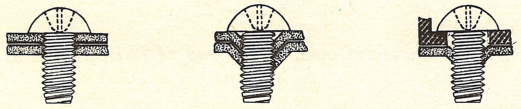
Sheet metal screws are used extensively in holding sheet metal parts together, Fig. 2-5. A hole is first punched or drilled into the sheet metal, and then the screw is turned into the hole.

NUTS

There are two broad classifications of nuts: square and hexagon. See Fig. 2-1. The hexagon is further divided into plain hex and slotted or castellated. The square-headed nut is used occasionally in body construction. The plain hex nut is generally used in connection with some type of lock washer, Fig. 2-1. The slotted or castellated nut is designed for use with a cotter pin, which of course necessitates a hole through the end of the bolt or stud, through which the cotter pin can pass.



2-4. Types of sheet metal screws.



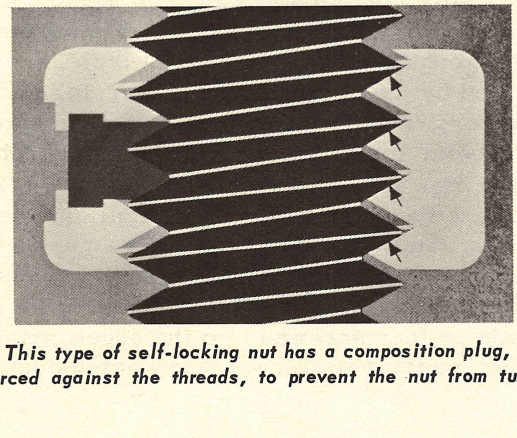
To join two thicknesses of light gauge sheet metal, drill or clean punch both sheets.

Stronger fastenings are made by piercing both sheets together so that burrs are nested.

Holes in light gauge sheet metal should be burred when fastening part with holes provided.

2-5. Different methods of using sheet metal screws.

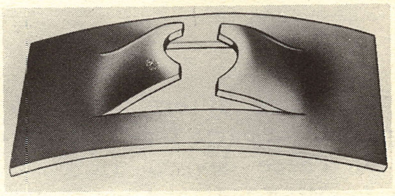
Another type of nut which is coming into extensive use, incorporates in its design a self-locking device, Fig. 2-6. There are several different designs of these self-locking nuts which are used extensively in such places as valve tappet screws, and connecting rod bolts.



2-6. This type of self-locking nut has a composition plug, which is forced against the threads, to prevent the nut from turning.

SPEED-NUTS

In order to reduce the time of assembly of parts, the speed-nut was developed. There are many different types of speed-nuts and clips. A speed-nut, Fig. 2-7, is simply pressed onto the bolt or stud and it takes the place of the conventional threaded nut and lock washer.

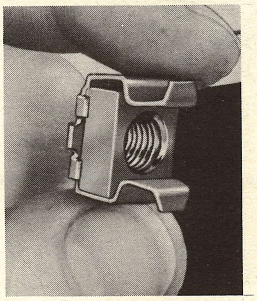


2-7. Flat type speed nut, or self-locking nut. These take less time to apply and provide maximum holding power.

Speed clip nuts, Fig. 2-8, are snapped onto the sheet metal, are self aligning, and are used in blind locations such as radiator grilles.

LOCKWASHERS

Lockwashers are installed under the head of a screw, or under a nut, so that they will not become loose as the result of vibration. There are three major types of lockwashers: the plain, external and internal. See Fig. 2-1. In addition there is one with both internal and external teeth, but it is used infrequently.



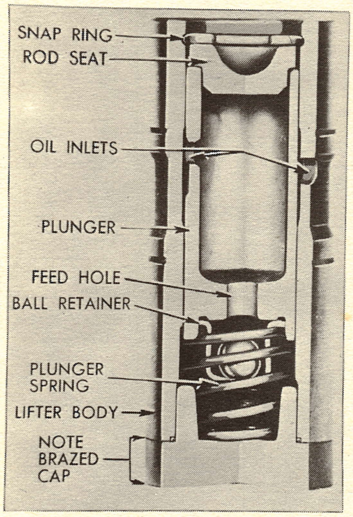
2-8. Speed clip nuts are used in blind locations such as radiator grilles. They are self aligning and are snapped onto the sheet metal.

SNAP RINGS

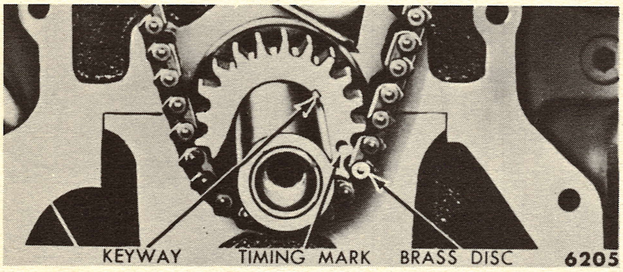
Snap rings, Fig. 2-9, are employed to prevent endwise movement of cylindrical parts and shafts. There are both internal and external snap rings. The internal type snap ring is used in a groove cut in a housing, while the external type snap ring is designed to fit in a groove cut on the outside of a cylindrical piece such as a shaft. They are used extensively in manual shift and automatic transmissions, and also in hydraulic valve lifters.

KEYS AND SPLINES

Keys and splines are used to lock gears, and other parts to shafts so that they will rotate as a single unit. The keys used most frequently in automotive design include the woodruff key, sunk key and gib-head key. The keys fit into slots known as keyways, Fig. 2-10, which are cut into both the shaft and the mating part. The design is such that the key will extend into both parts so that they will rotate as one.



2-9. Showing how a snap ring is used to hold an assembly together.

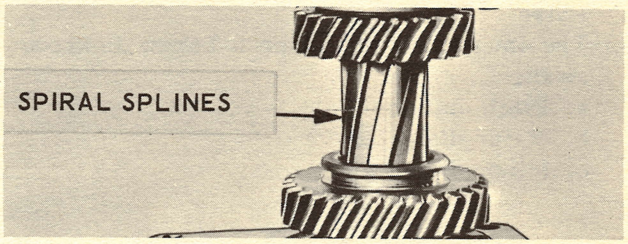


2-10. Note the keyway on the timing gear.

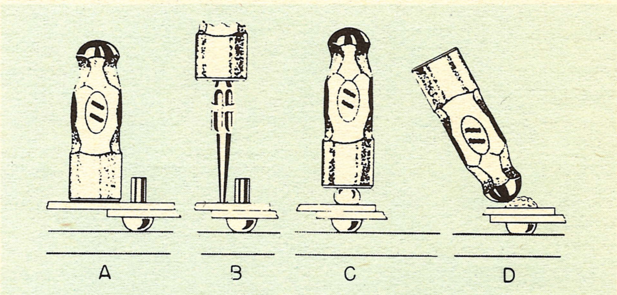
Splines are external teeth cut on a shaft, Fig. 2-11, and corresponding internal teeth cut on the mating part. In effect, they are mating internal and external gears with a 1 to 1 ratio. Splines are used in the design of transmission, propeller shafts, and rear axle assemblies.

RIVETS

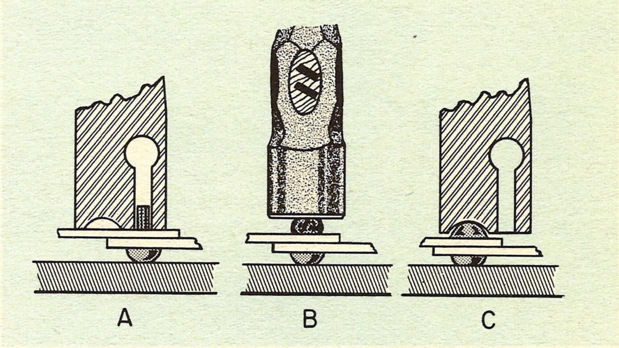
A rivet is a metal pin with a head at one end, and is designed to fasten two parts together. After the rivet is passed through the holes in the parts to be joined, the small end of the rivet is formed into a head by means of a rivet set, or by using the peen end of a ball peen hammer, Fig. 2-12.



2-11. Note the spiral splines on this transmission main shaft.



2-12. When a rivet set is not available, first drive the two parts together and onto the rivet head as in A and B. Then rivet over the rivet head as at C and D.



2-13. Procedure when using a rivet set.

In addition to using rivets for holding pieces of metal together, rivets are also used extensively for fastening brake lining to brake shoes.

When a rivet set is available, the steps A, B and C, Fig. 2-13 are followed.

QUIZ - FASTENING DEVICES

1-What is the major difference between a machine screw and a bolt?

2-A stud has threads on one end. True_____ False_____.

3-The largest diameter on a screw is known as the:

a. Pitch diameter
b. Major diameter
c. Minor diameter

4-Most bolts have what shape head?

a. Square head
b. Octagonal head
c. Hexagonal head
d. Round head

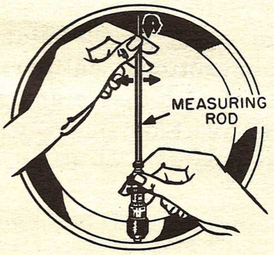
5-What type of nut is used with a cotter pin?

6-Name two methods used to keep nuts from becoming loose on a bolt.

7-What is the purpose of a spline?

MEASURING INSTRUMENTS

A micrometer is an instrument designed for linear measurement with accuracy of .001 in. or better. One type, known as the inside micrometer, Fig. 3-1, is used for measuring the distance between two parallel surfaces, and for measuring the inside diameter of cylinders. The outside micrometer, Fig. 3-2, is designed to measure the outside diameter of cylindrical forms and also the thickness of materials. On the outside micrometer, the spindle C, is attached to the thimble E, on the inside, at the point of adjustment which is often provided with a ratchet stop F. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame A. The frame being stationary, the thimble E is revolved by the thumb and finger, and the spindle C being attached to the thimble, revolves with it and moves through the nut in the frame, approaching or receding from the anvil B.



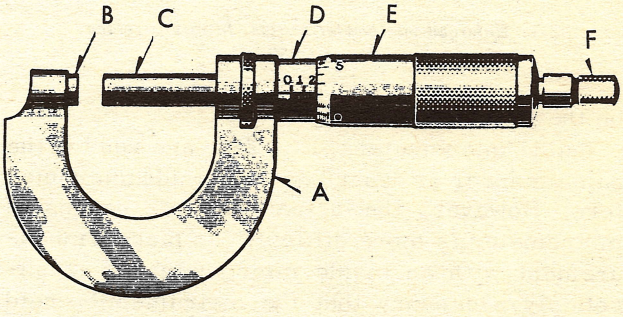
3-1. Using an inside micrometer to measure a diameter. The size can be extended by means of the measuring rod.

The measurement of the opening between the anvil and the thimble is indicated by the line and figures on the sleeve D and the thimble E.

The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle, therefore, moves it longitudinally 1/40th or .025 in. The sleeve D is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the micrometer is closed, the bevelled end of the spindle coincides with the line marked 0 on the sleeve, and the 0 mark on the thimble also coincides with the horizontal line on the sleeve.

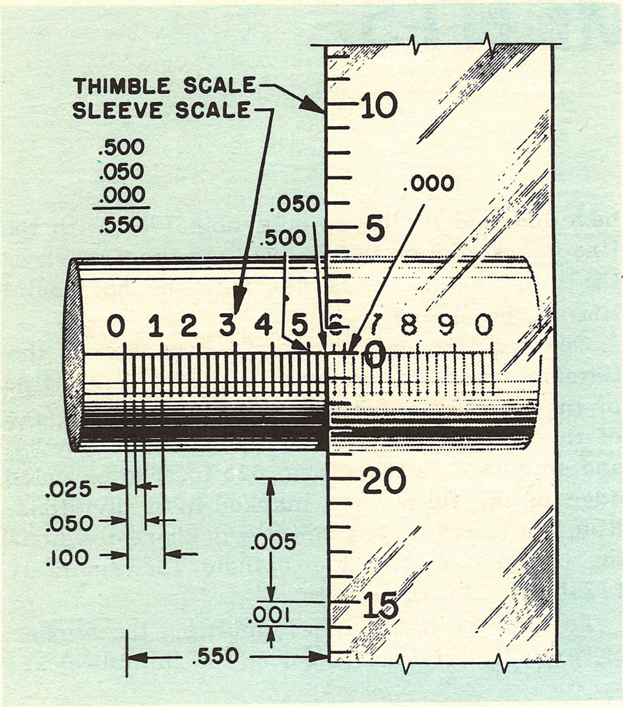
Opening the micrometer by revolving the thimble one full revolution will make the 0 line of the thimble coincide with the horizontal line of the sleeve. The distance between the anvil B and spindle C is therefore .025 in. The bevelled edge of the thimble is marked in 25 divisions. Rotating the thimble from one of these divisions to the next moves the spindle longitudinally 1/25th of .025, or .001 in.

To read the micrometer, multiply the number of vertical divisions visual on the thimble by 25, and add the number of divisions on the bevel of the thimble from 0 to the line which coincides with the horizontal line on the sleeve. In the enlarged portion of the micrometer shown in Fig. 3-3, the reading would be .550 in. Fig. 3-4 shows the correct method of holding a micrometer, and the reading happens to be .260 in.



3-2. Typical outside micrometer.

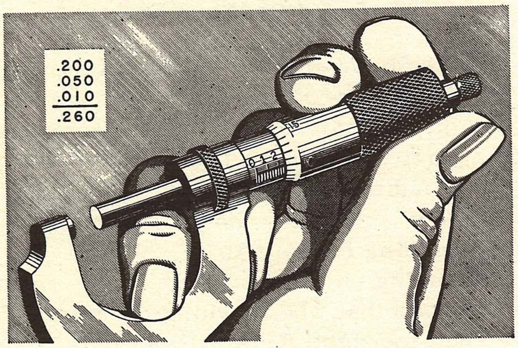
When using a micrometer, care must be exercised so that when turning the thimble it is not turned too tight. This will not only result in distortion of the frame and consequent inaccuracy of the readings but will also result in wear of the screw threads. Only gentle pressure should be used. To overcome this difficulty, some micrometers, as shown in Fig. 3-2, are provided with a ratchet drive, (indicated by the letter F), on the thimble so that regardless of who uses the micrometer the same pressure will be exerted on the thimble.



3-3. *Enlarged micrometer scales. In this case the reading is .550 in.*

Inside micrometers, Fig. 3-1, are read in the same manner as described for outside micrometers. However, the actual use of the inside micrometer is more difficult. To make a measurement with an inside micrometer, it is absolutely necessary that the instrument be held so that it is perpendicular to the two surfaces.

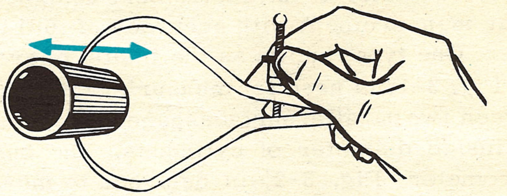
For automotive work, micrometers reading up to 5 in. are needed. Most micrometers have a range of reading of only 1 in. However, other types are available which have interchangeable anvils so that one instrument will have a wide range of reading.



3-4. *Correct method of holding a micrometer.*

Special micrometers for measuring the diameters of crankshaft main bearing journals (after removing the bearing cap, but without removing the crankshaft) are available.

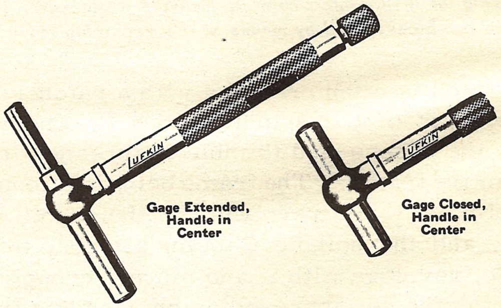
Another type of micrometer is designed to measure the thickness of engine bearing shells, and in that way determine the extent of wear. The anvil of such micrometers is rounded, so that point contact is made on the inner surface of the bearing, while the spindle contacts the outer surface.



3-5. *Using a pair of outside calipers for measuring a diameter.*

When the accuracy of the micrometer is not needed, the conventional caliper, Fig. 3-5, is used. Calipers of both inside and outside measurements are available, and with care, accuracy in measurement of .01 in. can be easily attained.

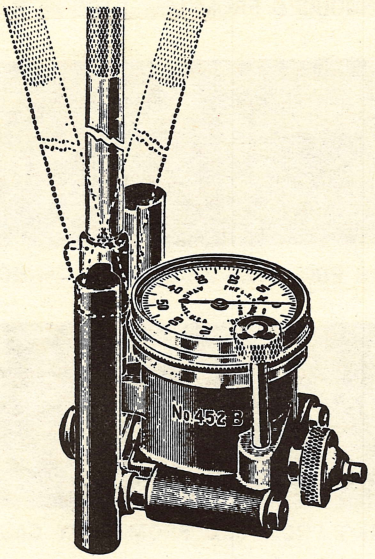
For measuring the diameter of small holes, telescoping gauges are available, Fig. 3-6. After adjusting the gauge in the hole so that it fits snugly, the gauge is removed, and the diameter of the gauge is then measured with a conventional micrometer.


LUFKIN
Gage Extended, Handle in Center
LUFKIN
Gage Closed, Handle in Center

3-6. *A telescoping gauge is used to measure small diameters or the inside size of slots.*

DIAL GAUGES

To measure the amount of out-of-round and taper in an engine cylinder, a dial gauge, Fig. 3-7, is usually used. Such gauges are inserted in the cylinder bore, and as the gauge is moved up and down in the cylinder, movement of the indicating needle of the gauge will show the variation in measurement. Similarly, the amount of out-of-round is measured by rotating the gauge in the cylinder. Such gauges are calibrated to read in .001 in.

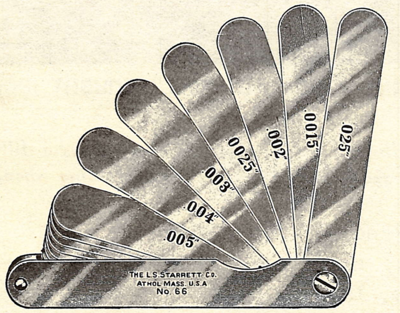


3-7. Dial gauges are used extensively to measure the diameter and wear of engine cylinders.

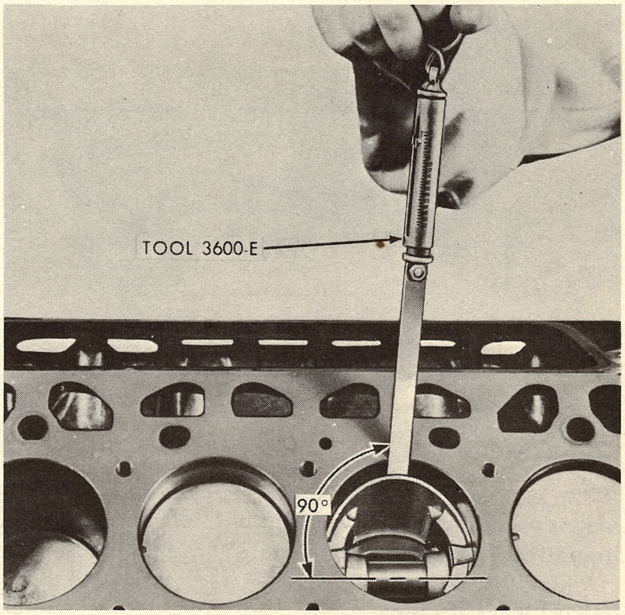
By means of a special fixture, dial gauges are also used extensively for measuring the backlash of gears. This is particularly important to the adjustment of the rear axle, pinion and ring gear.

THICKNESS GAUGE

The thickness or feeler gauge is used extensively for measuring the distance between two surfaces, when those surfaces are only a few thousandths of an inch apart. As shown in Fig. 3-8, a feeler gauge consists of an assortment of steel strips of graduated thickness. Each blade of the gauge is marked with its thickness in thousandths of an inch. To use such a gauge, a blade is inserted in the space to be measured, and the gauge blade that fits snugly in the space, is then equal to that space in thousandths of an inch. Thickness or feeler gauges are used extensively for measuring valve tappet clearance, ignition breaker point spacing, and the gap of spark plugs.



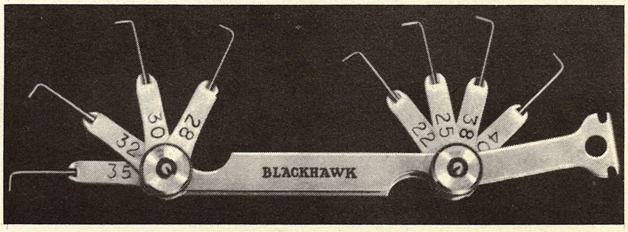
3-8. Typical thickness or feeler gauge used for measuring the width of small spaces.



3-9. Using a feeler gauge and a spring balance to check the clearance between a piston and the cylinder.

When used to measure the clearance between a piston and a cylinder, the force required to withdraw the gauge is measured by a spring balance, Fig. 3-9.

In adddition to the flat blade type of thickness gauge, gauges made of different diameter wire, Fig. 3-10, are also used. Such gauges are used particularly for measuring the gaps of ignition breaker points, and spark plug gaps.

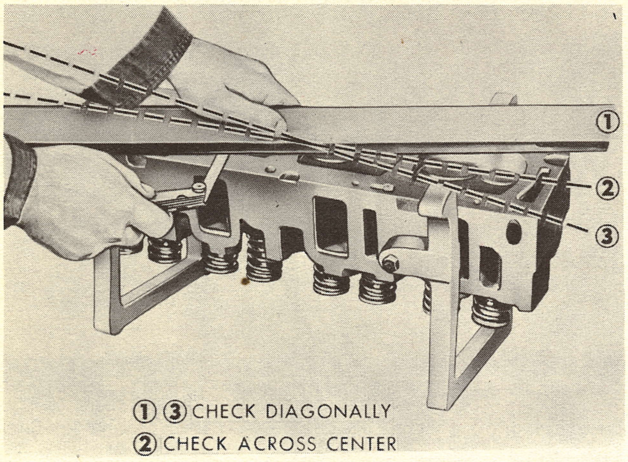


3-10. The wire type of thickness gauge is usually used to measure spark plug gaps. Note bending lever on right.

Other gauges used frequently in the automotive service field include wire gauges, screw pitch gauges, and vernier calipers.

STRAIGHTEDGE

A straightedge is used frequently to check the trueness of a surface. In Fig. 3-11, a cylinder head is being checked for warpage with a straightedge and the amount of warpage is measured by means of a feeler gauge.



3-11. Using a straight edge and a feeler gauge to measure the warpage of a cylinder head.

IDENTIFYING METALS

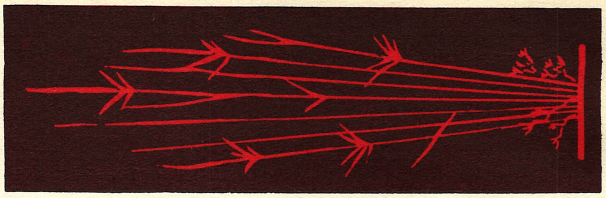
In automotive work, it is important to be able to identify different metals. In the case of ferrous metals, that is, iron and its alloys, these can be easily identified by holding a sample of material against an abrasive wheel. By noting the character of the sparks the metal can be identified. Figure 3-12 shows the sparks given by various metals, the length of the spark screen, its color and the type of spark. Note that in the case of low carbon steel the spark stream is long, and the volume moderately large. In high carbon steel, the stream is shorter but the volume is larger. Stainless steel produces a moderate volume with few sparklers.

When making such tests, moderate pressure should be used and care exercised that always the same amount of pressure is applied for all tests.

Copper can be easily identified by its appearance, as the American one cent piece is made out of copper. Brass is an alloy consisting of copper and zinc, and in appearance is more yellow than the familiar copper. However, its color will vary with the amount of zinc used in the alloy.

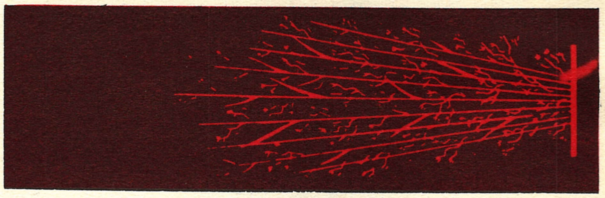
Bronze is an alloy consisting chiefly of copper and tin. Usually it is not as yellow as brass, and is also generally harder.

A



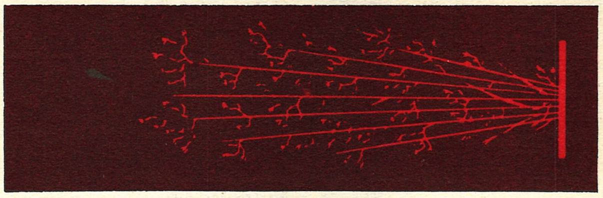
SPARKS PRODUCED FROM LOW-CARBON & CAST STEEL

B



SPARKS PRODUCED FROM HIGH-CARBON STEEL

C

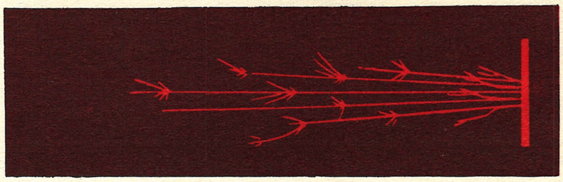


SPARKS PRODUCED FROM GRAY CAST IRON

D

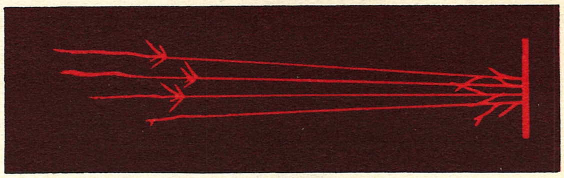
SPARKS PRODUCED FROM NICKEL

E



SPARKS PRODUCED FROM STAINLESS STEEL

F



SPARKS PRODUCED FROM WROUGHT IRON

3-12. As illustrated, each type of metal gives a different type of spark when held against a grinding wheel.

Nickel, somewhat resembling silver in appearance, is easily recognized as the familiar American 5¢ piece is made of that metal.

QUIZ - MEASURING INSTRUMENTS

1-For what purpose are inside micrometers frequently used in automotive service work?

2-When the thimble of a micrometer is turned one division as indicated by the lines on the beveled edge of the thimble, how far has the spindle moved?
  a. .025 in.
  b. .0025 in.
  c. .001 in.
  d. .005 in.

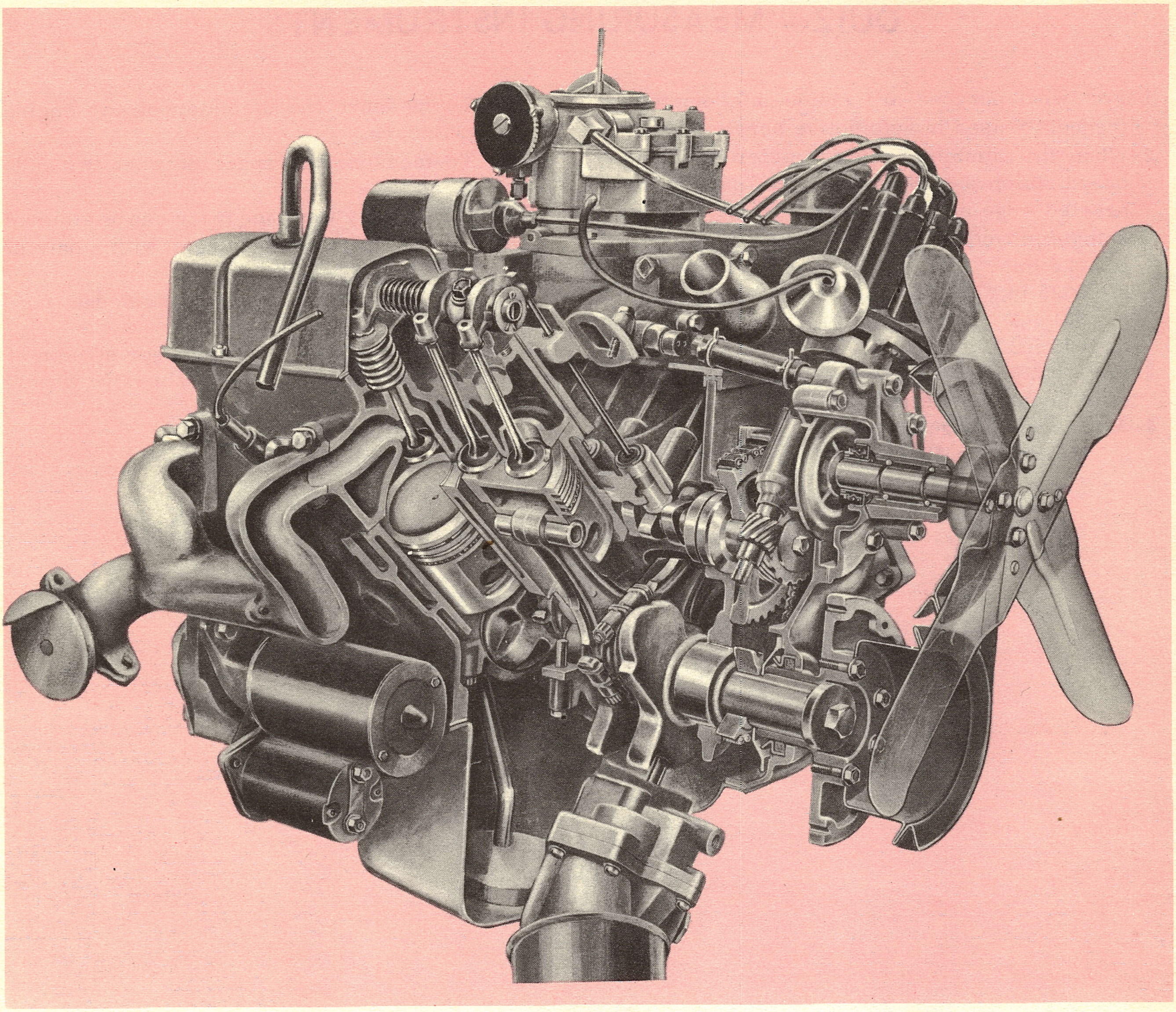
3-For what purposes is a dial gauge frequently used in automotive service work?

4-A thickness gauge is used:
  a. To measure the thickness of sheet metal
  b. To measure the diameter of car engine cylinders
  c. To measure the space between two surfaces

5-Approximately what accuracy can be attained when making a measurement with a pair of conventional calipers?

6-For what purpose is a straightedge frequently used?

7-Which metal produces the longer stream of sparks when held against an abrasive wheel?
  a. Nickel
  b. High carbon steel
  c. Low carbon steel



Engine section view, Buick Special.

ENGINE FUNDAMENTALS

Automobiles have been operated successfully by electric motors, steam engines, and internal combustion engines. The internal combustion engine burns fuel within the cylinders, and converts the expanding force of the combustion or "explosion" into rotary mechanical force used to propel the vehicle.

The internal combustion engine, generally known as a "gasoline engine" has had almost complete dominance for a half century. As a result of this dominance, it has been highly developed and refined. It has become a mechanical marvel of power, flexibility and reliability, and at the same time has overcome to a great extent the basic faults of vibration and noise.

ENGINE FUELS

These engines can be made to operate on almost anything that can be converted into a gas that will burn. For example; wood, coal, alcohol, vegetable oils, mineral oils, etc. Some form of petroleum product is almost universally used however because of convenience.

A wide variety of petroleum products are used as fuel: gasoline, kerosene, fuel oil, liquefied petroleum gas (LPG), etc. When kerosene, fuel oil, or LPG is used, it is necessary to alter the design or equipment of the engine to other than standard gasoline engine practice.

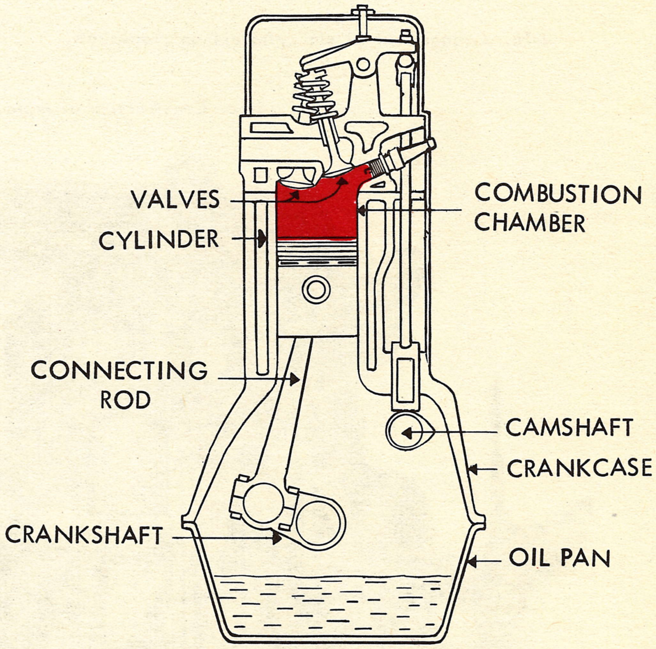
ENGINE DESIGN

Gasoline engines for use in automobiles are made in infinite variations; two-stroke cycle, four-stroke cycle, water cooled, air cooled and with various numbers of cylinders. There is also wide variation in the design of almost all the parts of the engine.

The typical automobile engine, standard for a great many years, has been a reciprocating piston, four cycle, water cooled, poppet valve, gasoline engine.

RECIPROCATING ENGINES

Each "cylinder" of the typical automobile engine has a "piston" which reciprocates--or moves back and forth--within the cylinder and is connected to the "crankshaft" by means of a link known as a "connecting rod." See Figs. 4-1a, 4-1b, and 4-1c.



4-1a. Arrangement of parts in one cylinder.

Other types of reciprocating engines substitute an eccentric, an inclined plate, or a cam mechanism for the crankshaft. The "free piston" engine has no crankshaft or connecting rods.

ROTARY ENGINES

Rotary types of engines are not as yet widely used in automobiles. As they are somewhat similar to turbines, they are described herein under that heading.

ENGINE OPERATING SEQUENCE

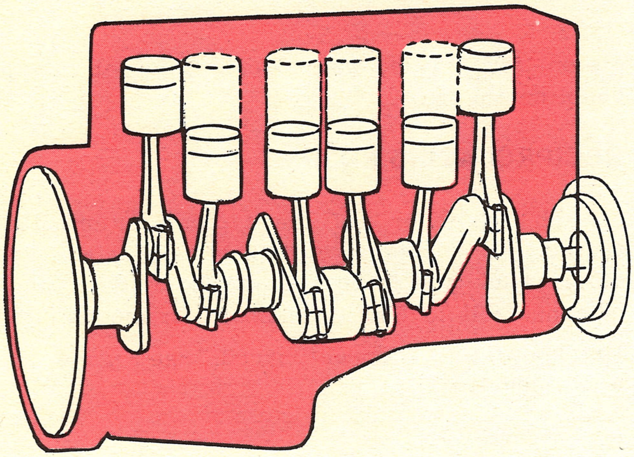
In any internal combustion engine, there is a definite series of events that must occur in sequence. They are:

A. Fill the cylinder or chamber with an explosive mixture.
B. Compress this mixture into a smaller space.
C. Ignite the mixture or cause it to explode.
D. Utilize the explosive or expansive force for power production.
E. Remove the burned out mixture from the cylinder or chamber.

This series of events must be repeated over and over in the same sequence automatically in each cylinder if the engine is to run.

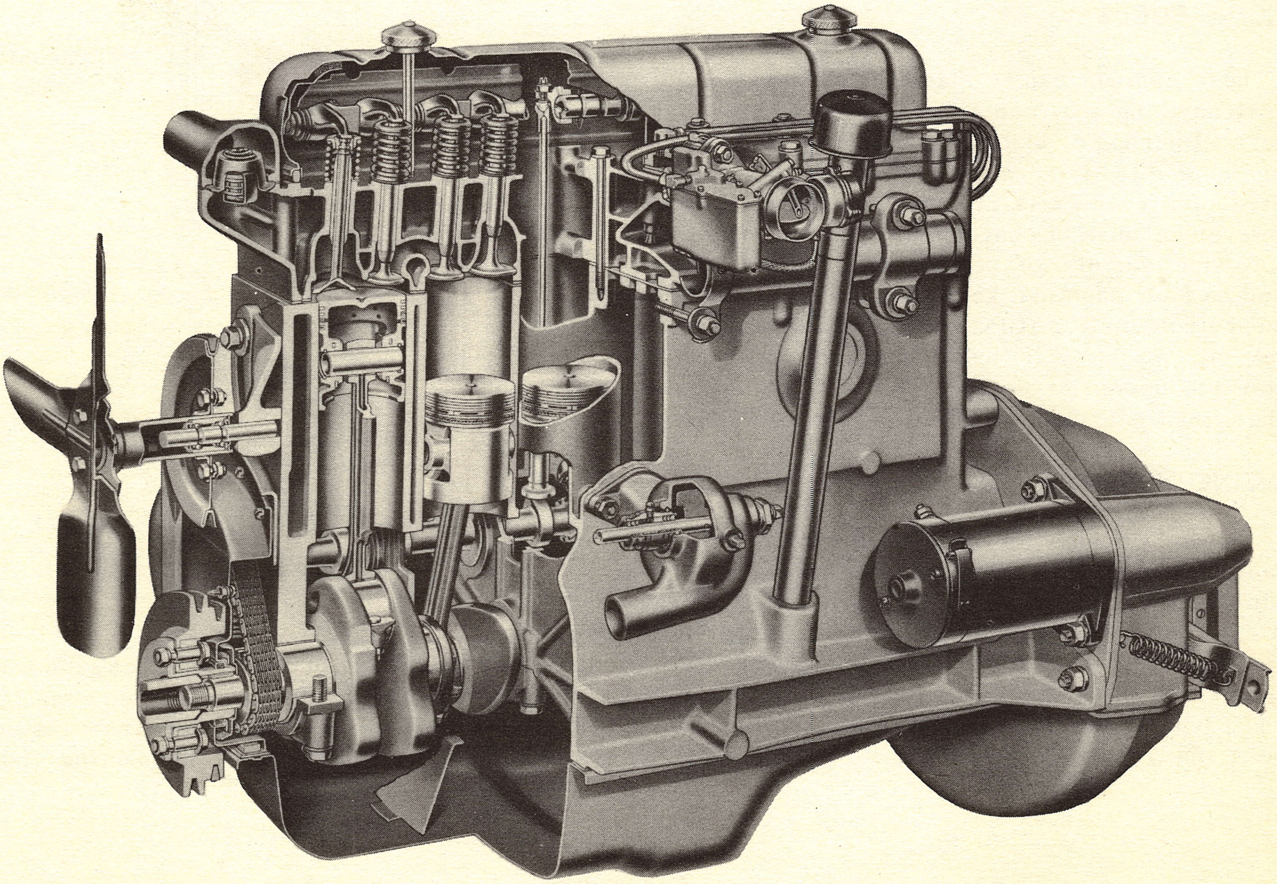
The first requisite is to fill the cylinder with an explosive mixture. If gasoline is the fuel, it must be mixed with the proper proportion of air. It must be mixed with air in the proportion of 10 to 15 parts of air, to each part of gasoline, in order to operate in a gasoline engine. Such a mixture is compounded automatically and continuously by a device known as a carburetor, which is described elsewhere in this text.

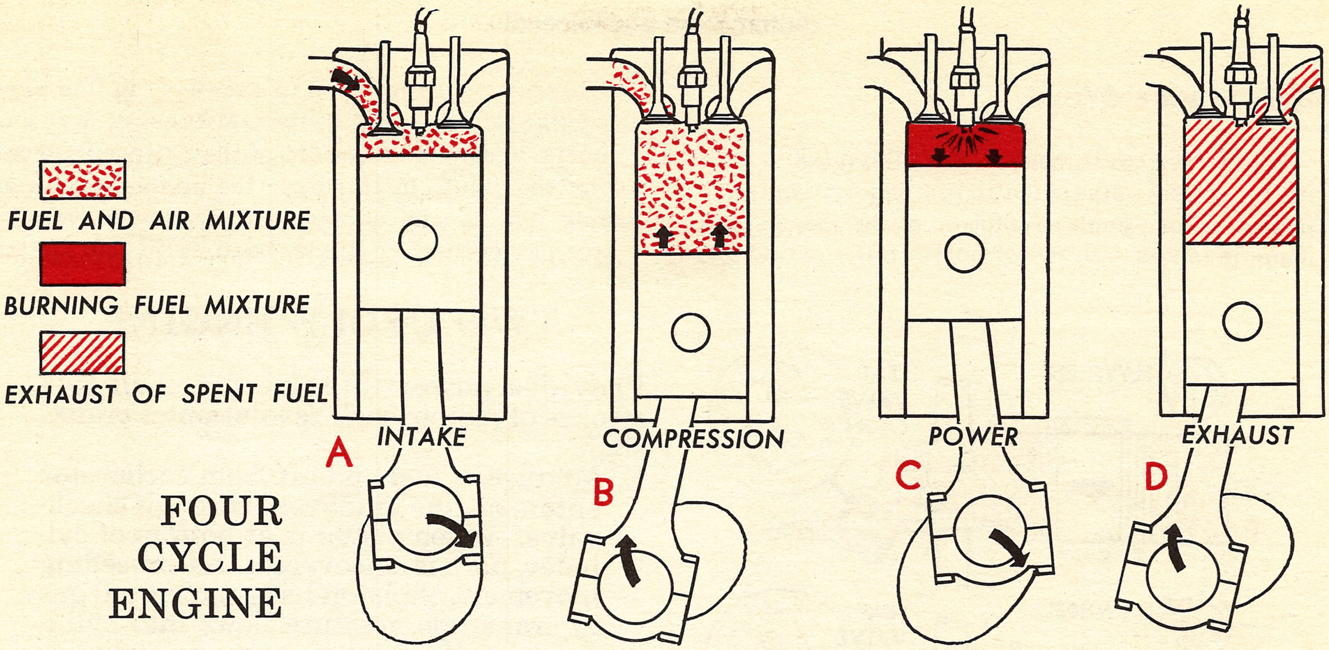
If the fuel is fuel oil such as in a Diesel engine, the oil is injected into the cylinders under high pressure as described in the section of this text devoted to Diesel engines In some Diesel en-



4-1b. Arrangement of six cylinders on crankshaft.

4-1c. Construction of typical six cylinder overhead valve engine.




FUEL AND AIR MIXTURE
BURNING FUEL MIXTURE
EXHAUST OF SPENT FUEL
A
INTAKE
B
COMPRESSION
C
POWER
D
EXHAUST

FOUR CYCLE ENGINE

Provides one power impulse for four strokes of piston; each two revolutions of crankshaft.

A. On Intake Stroke, inlet valve opens; piston draws fuel and air mixture into cylinder.

B. On Compression Stroke, both valves are closed. Rising piston compresses mixture.

C. At upper limit of piston movement; both valves closed, mixture is ignited. Explosion forces piston downward on Power Stroke.

D. On Exhaust Stroke, exhaust valve opens, rising piston pushes spent gas from cylinder.

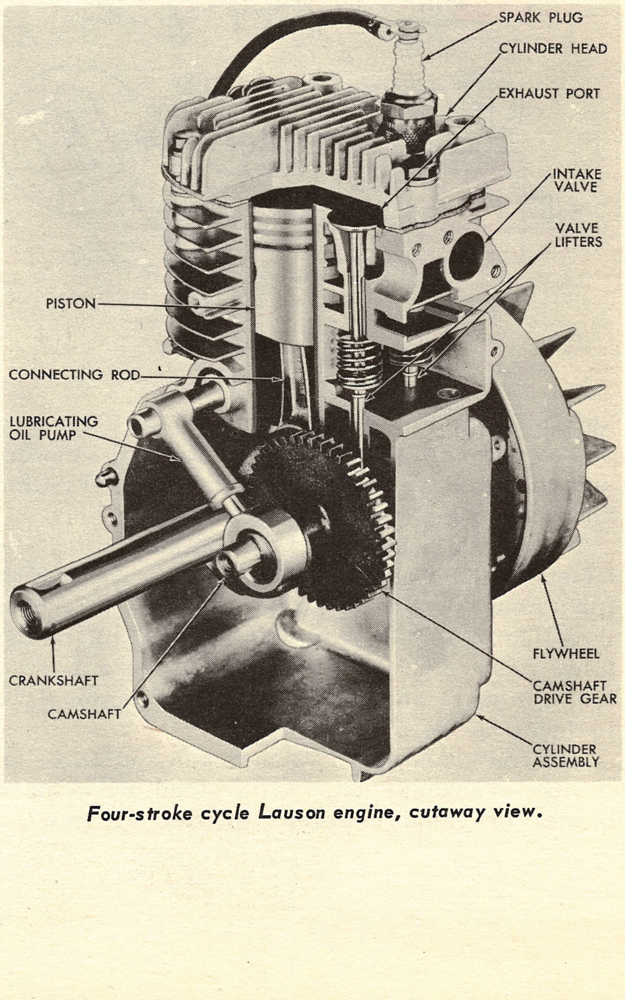
Fig. 4-2.

gines, the heat generated by compressing the air in the cylinder may be used to ignite the fuel. In gasoline engines, an electrical spark is utilized. The method of creating and delivering this spark to each cylinder at the proper time is described in the Electrical Section of this text.

FOUR-STROKE CYCLE

The majority of automobile engines operate on the four-stroke cycle, and are known as "four cycle" engines. Another name for this cycle is "Otto cycle" after the name of the inventor. The power production cycle consists of four strokes of the piston in a reciprocating engine--one inward in the cylinder and one outward--in each of the two revolutions of the crankshaft required to complete the cycle. See Fig. 4-2.

In order to fulfill the first requisite, it is necessary to fill the cylinder with an explosive mixture. This is accomplished by the atmospheric pressure pushing the mixture into the cylinder, after the piston has created a vacuum in the cylinder by moving toward the crankshaft. The mixture is conducted from the carburetor through a pipe known as a manifold, and is regulated by the opening and closing of a valve. These valves will be studied in detail later.


SPARK PLUG
CYLINDER HEAD
EXHAUST PORT
INTAKE VALVE
VALVE LIFTERS
PISTON
CONNECTING ROD
LUBRICATING OIL PUMP
CRANKSHAFT
CAMSHAFT
FLYWHEEL
CAMSHAFT DRIVE GEAR
CYLINDER ASSEMBLY

Four-stroke cycle Lauson engine, cutaway view.

TWO-STROKE CYCLE

In the two-cycle engine, the piston takes over some of the valve function in order to obtain a power stroke each revolution of the crankshaft. This involves the use of ports in the cylinders, as shown in Fig. 4-3. These ports are covered and uncovered by the movements of the piston, and thus act as a valve in controlling the filling and emptying of the cylinder.

It must be understood that both inlet and exhaust ports are covered by the piston, except for a short time at the extreme end of the stroke. A deflector is placed on top of the piston on the inlet side, to divert the fresh mixture up into the cylinder while the exhaust is leaving the cylinder on the opposite side.

Alternate phases of vacuum and compression in the crankcase can be avoided by using a blower or "supercharger" to push air into the cylinder as illustrated in Fig. 4-4. In this particular design (used in the GM Diesel), a row of ports around the bottom of the cylinder serves for the inlet. In this case the piston acts as an inlet valve, and cam-operated exhaust valves, are placed in the cylinder head. In this design the blower pumps air into the cylinder, and the fuel is pumped in under pressure as explained in the section of this text devoted to Diesel engines.

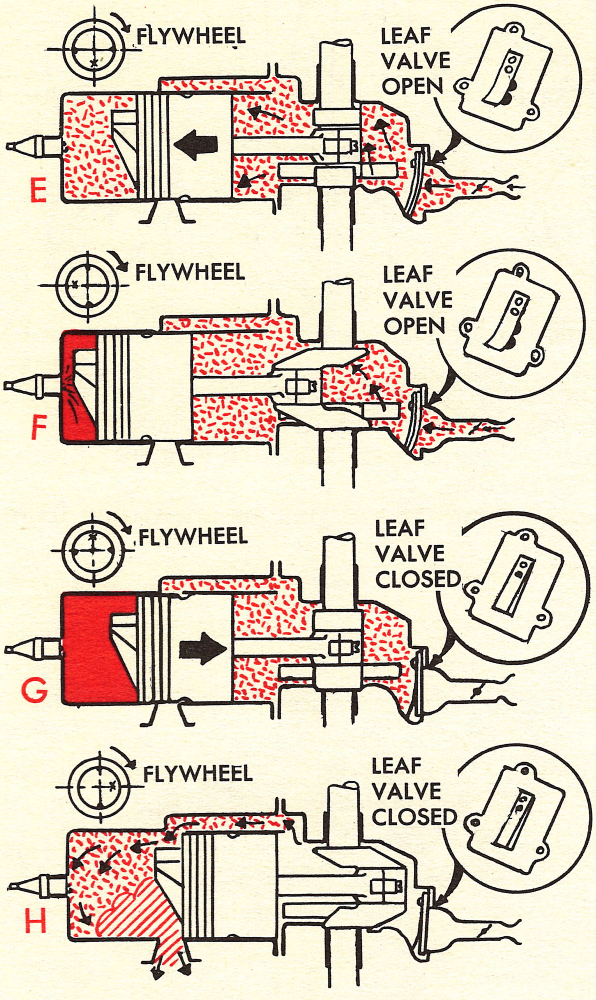


Fig. 4-3. Two-cycle engine.

TWO CYCLE ENGINE

Provides power impulse for each two strokes of piston; each revolution of crankshaft.

E. Mixture of fuel and air from carburetor enters engine crankcase through check-valve. When piston is at bottom of cylinder, port is uncovered. As preceding movement of piston has compressed gas in crankcase, mixture flows into cylinder. Further compression in cylinder starts as soon as piston reverses and covers ports.

F. At the same time compression is occurring in cylinder, movement of piston has created vacuum in crankcase which draws fresh charge of mixture from carburetor into crankcase. Charge is fired at limit of piston movement.

G. As expansion of burning charge forces piston downward, check-valve in crankcase closes and mixture in crankcase is compressed.

H. As piston uncovers ports at bottom of stroke, compressed mixture from crankcase enters cylinder and is deflected by baffle on piston head into outer end of cylinder. Incoming fresh mixture assists in pushing spent gas out of cylinder.

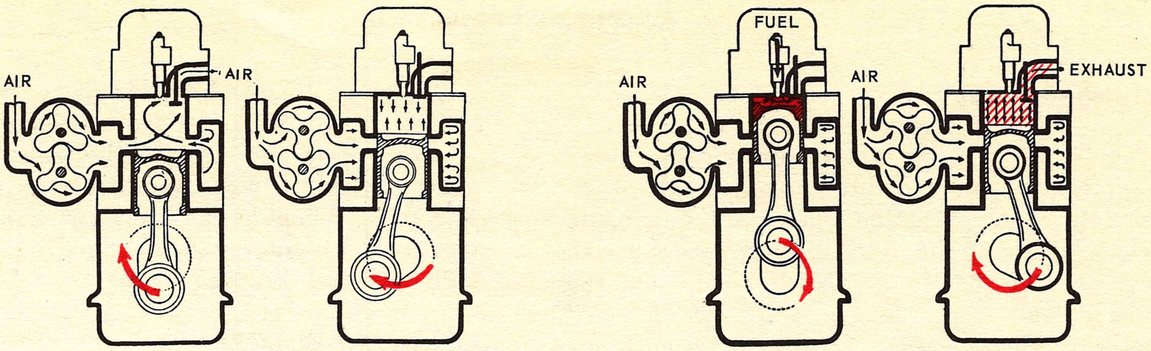
▨ *FUEL AND AIR MIXTURE*

■ *BURNING FUEL MIXTURE*

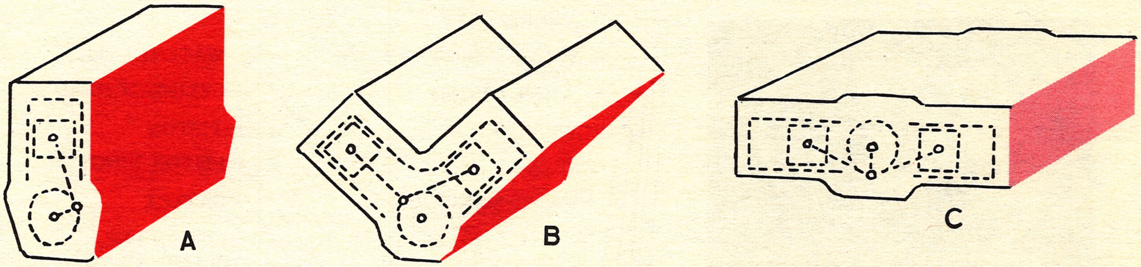
▧ *EXHAUST OF SPENT FUEL*

MULTI-CYLINDER ENGINES

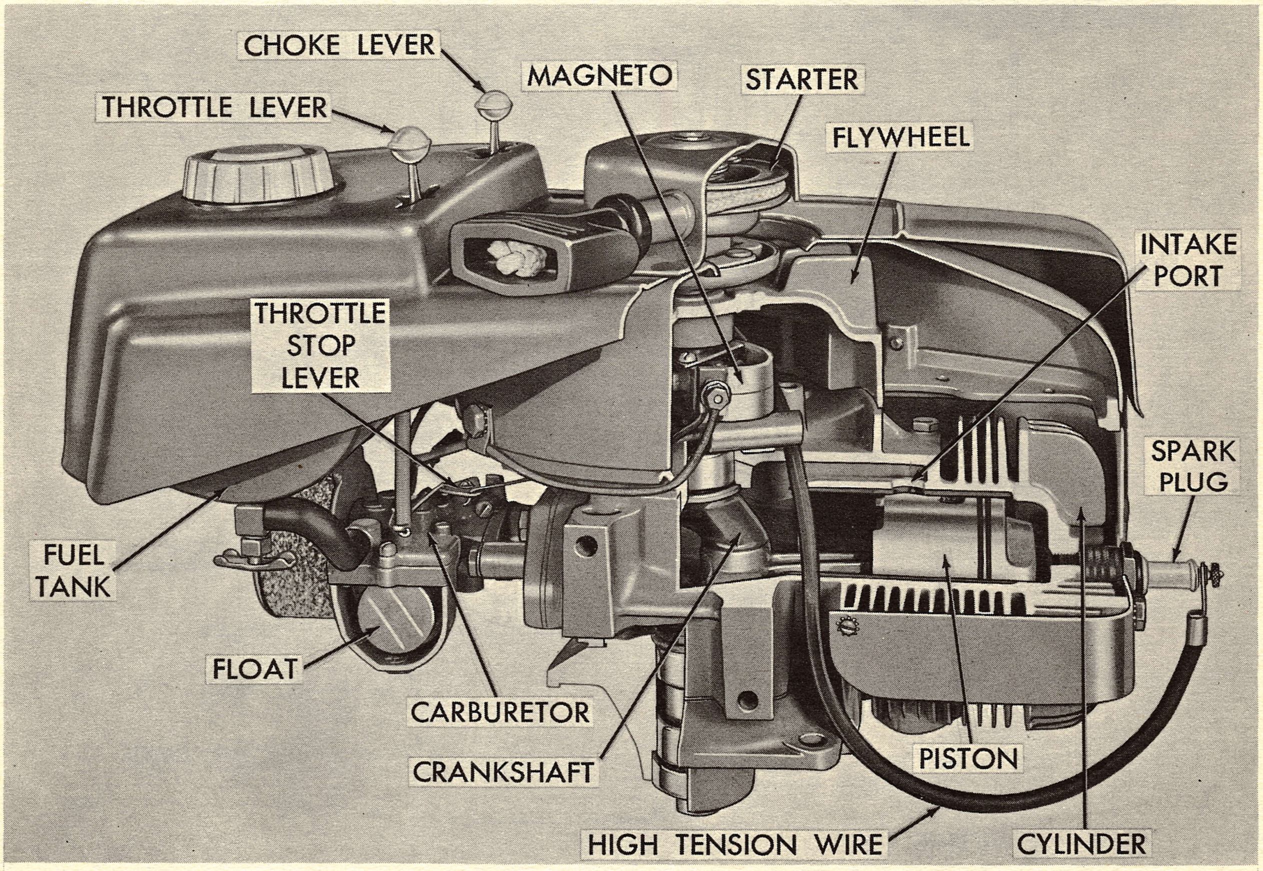
Almost all automobile engines--water cooled or air cooled--four cycle or two cycle--have more than one cylinder. These multiple cylinders are arranged in-line, opposed or in V form as shown in Fig. 4-5. Engines for other purposes, such as airplanes, utilize additional arrangements such as radial, inverted in-line, inverted V, X-shaped, and other forms.


AIR
AIR
FUEL
AIR
AIR
EXHAUST

4-4. In this type of two cycle engine, exhaust valves are used and a blower is utilized to push air into the cylinder through inlet ports, while the piston is used to push the exhaust gas out through exhaust valves.



4-5. Types of cylinder blocks. (A) In-line block, (B) V-type block, (C) Opposed or "flat" block.


CHOKE LEVER
THROTTLE LEVER
MAGNETO
STARTER
FLYWHEEL
INTAKE PORT
THROTTLE STOP LEVER
SPARK PLUG
FUEL TANK
FLOAT
CARBURETOR
CRANKSHAFT
PISTON
HIGH TENSION WIRE
CYLINDER

Two-stroke cycle Jacobsen engine, cutaway view.

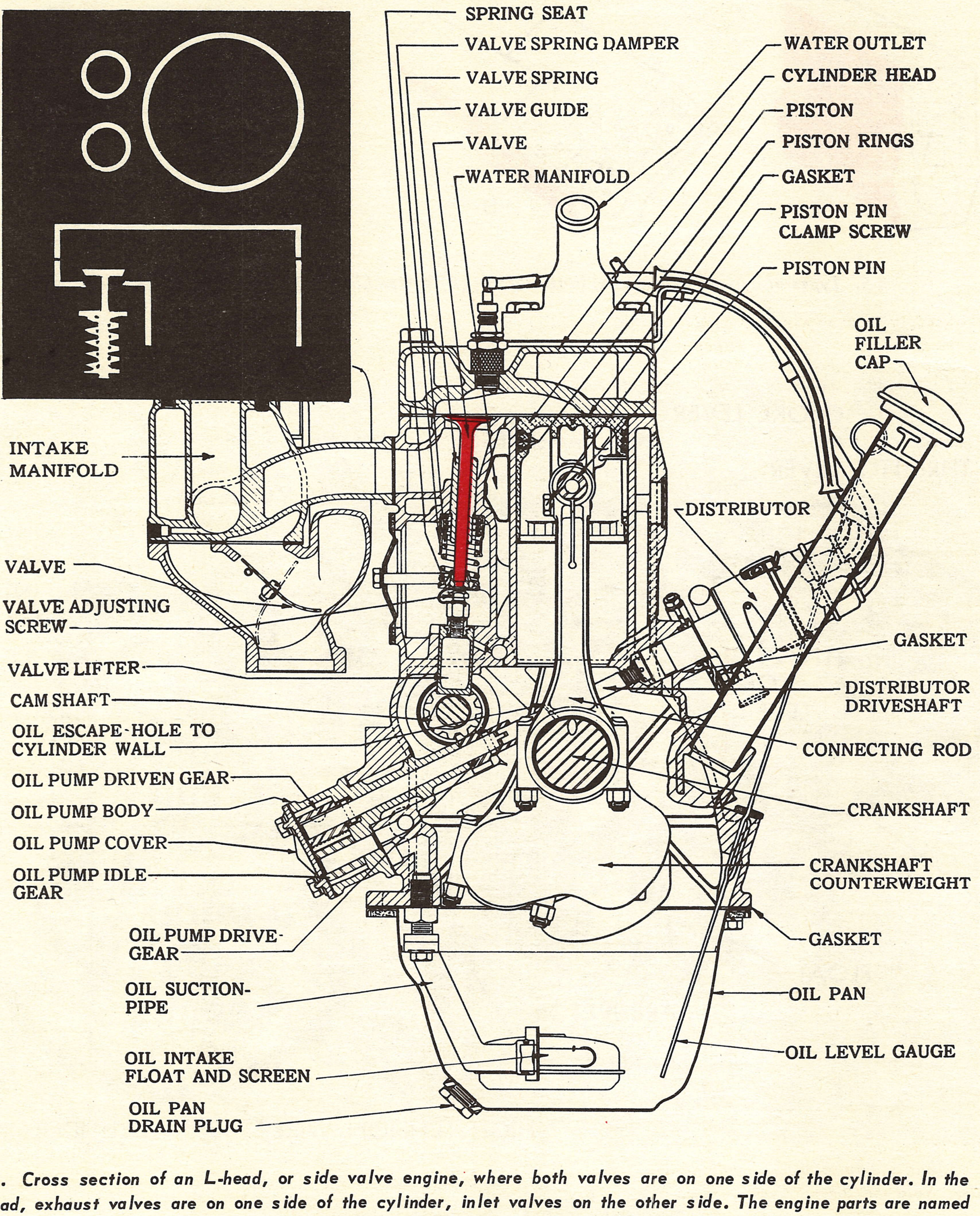
CYLINDER TYPES

The location of the valves in four-cycle engines, either water or air cooled, is one of the basic elements of design. There are four basic designs; three of which are in current use. These three are the "L head," the "I head," and the "F head," as shown in Fig. 4-6. The "T head" along with sleeve valves, rotary valves and other variations are not currently used in automobile engines.

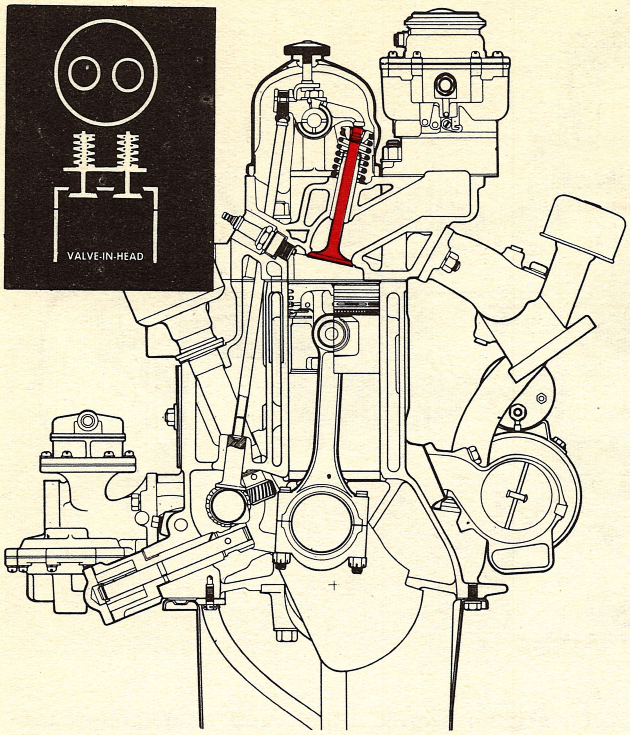
It should be noted that in the L-head design, the valve ports and gas passages are built in the cylinder block. In the I-head engine, these passages are built in the detachable cylinder head. The F-head engine has one valve in the head, and one in the block, with the necessary passages built into both head and block.

CYLINDER BLOCKS

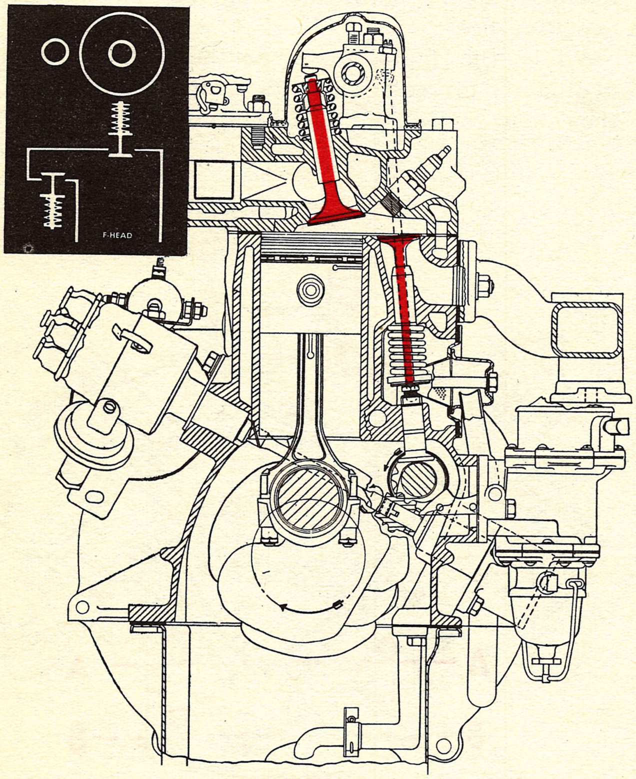
The engine crankcase and cylinder block, or


SPRING SEAT
VALVE SPRING DAMPER
VALVE SPRING
VALVE GUIDE
VALVE
WATER MANIFOLD
WATER OUTLET
CYLINDER HEAD
PISTON
PISTON RINGS
GASKET
PISTON PIN CLAMP SCREW
PISTON PIN
OIL FILLER CAP
INTAKE MANIFOLD
DISTRIBUTOR
VALVE
VALVE ADJUSTING SCREW
VALVE LIFTER
CAM SHAFT
OIL ESCAPE-HOLE TO CYLINDER WALL
OIL PUMP DRIVEN GEAR
OIL PUMP BODY
OIL PUMP COVER
OIL PUMP IDLE GEAR
GASKET
DISTRIBUTOR DRIVESHAFT
CONNECTING ROD
CRANKSHAFT
CRANKSHAFT COUNTERWEIGHT
GASKET
OIL PUMP DRIVE GEAR
OIL SUCTION-PIPE
OIL PAN
OIL LEVEL GAUGE
OIL INTAKE FLOAT AND SCREEN
OIL PAN DRAIN PLUG

4-6a. Cross section of an L-head, or side valve engine, where both valves are on one side of the cylinder. In the T-head, exhaust valves are on one side of the cylinder, inlet valves on the other side. The engine parts are named here and corresponding parts can be identified in the other forms.



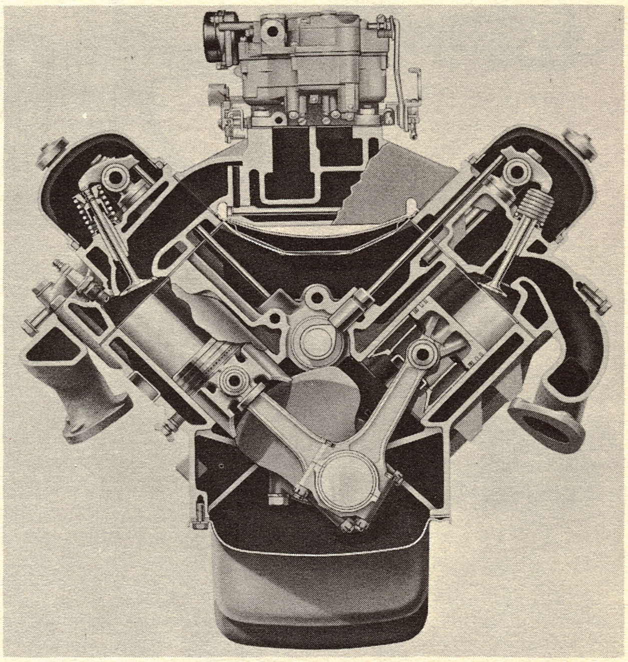
4-6b. In the I-head, also known as overhead valve or valve-in-head engine, both valves are placed directly over the piston. This design must not be confused with "overhead camshaft" engines described later.



4-6c. The F-head design is a combination of the L-head and I-head forms, as it has one valve in the head and one at the side of the cylinder. Note that each of these three designs uses a single camshaft to operate all valves.

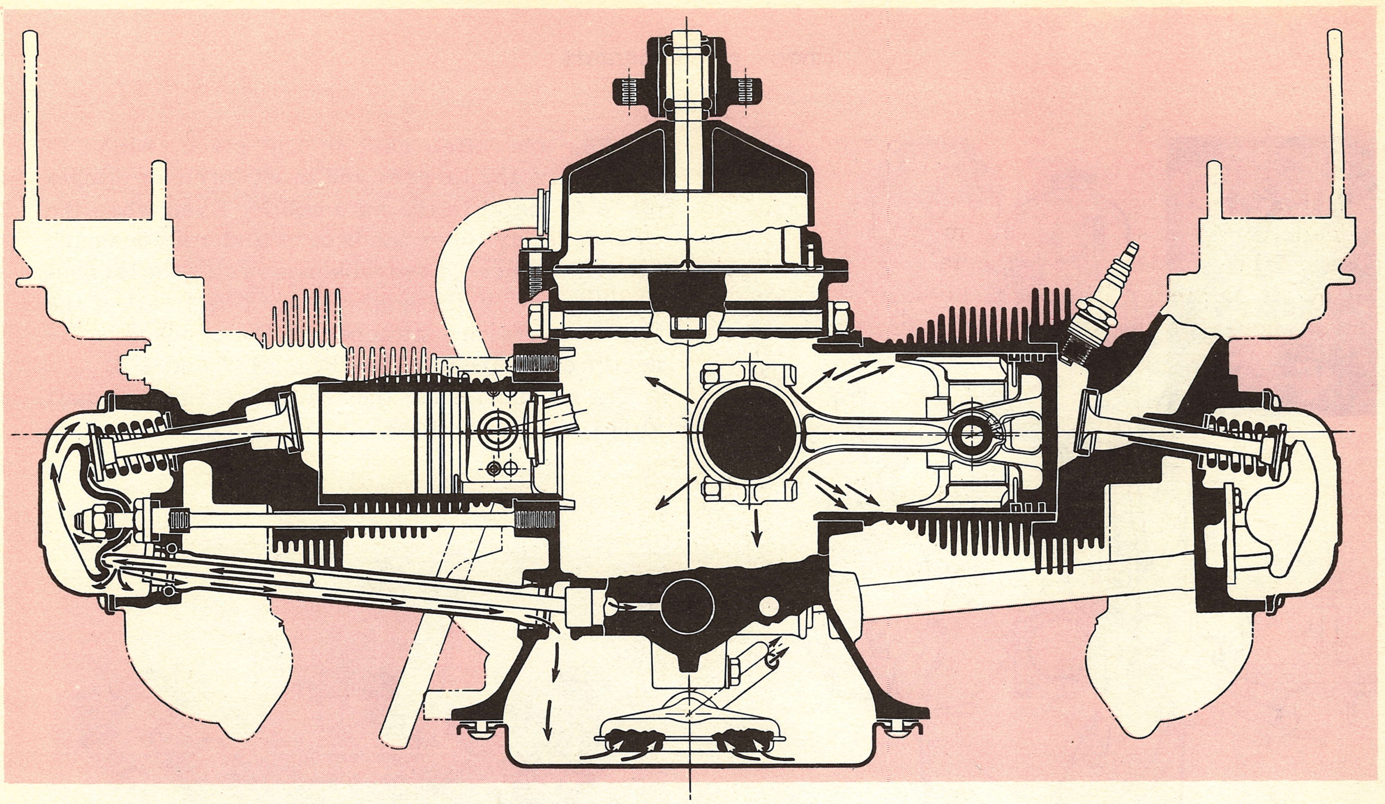
blocks, are often cast in one piece, which is ordinarily the largest and most intricate single piece of metal in the automobile. Even when the cylinders, cylinder heads or cylinder sleeves are separate pieces, the crankcase is still the largest single part in the engine. Practically all of the engine parts are attached to the crankcase directly or indirectly. See Figs. 4-7 and 4-8.

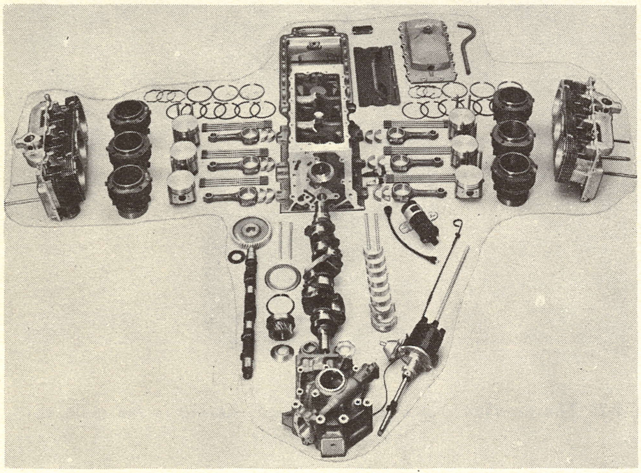
The crankcase has the crankshaft and camshaft attached to it, and with the oil pan which goes on the lower surface of the crankcase, forms an oil-tight housing in which the rotating and reciprocating parts operate. The cylinder block contains the pistons (except in the case of barrel cylinders as illustrated in Fig. 4-8), which are attached to the connecting rods and crankshaft. Much of the valve operating mechanism is also carried in the crankcase unit.



4-7. The crankcase and cylinder block casting is the main unit of most engines.

It is thus readily understood that this major unit must be extremely strong and rigid to avoid any bending or distortion. As this intricate casting varies in thickness, it does not always cool uniformly and internal stresses are created. These stresses sometimes cause warpage, but much has been done in the way of design to minimize the effects of warpage, by causing it to occur in such directions that it does not cause the cylinder bores to warp to any great extent or become excessively out-of-round. Dis-





4-8. *In this air-cooled Corvair engine, the cylinders are in the form of separate barrels, and are held to the crankcase by long studs. The crankcase is the core around which the engine is assembled.*

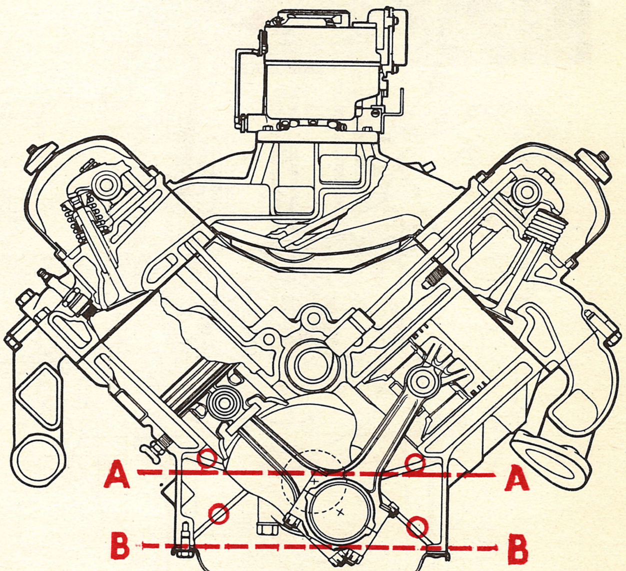
tortion may occur from incorrect placing of the metal masses around the cylinders, from expansion and contraction due to the heat of operation, or from excessive mechanical stresses placed upon it, such as unequal or extreme tightening of bolts, etc.

CYLINDER DISTORTION

This warpage or distortion can occur in several directions. The cylinder head surface can warp or twist, the cylinder bore may warp longitudinally or become out-of-round, the crankshaft or camshaft bearing bores may be warped out of line, etc.

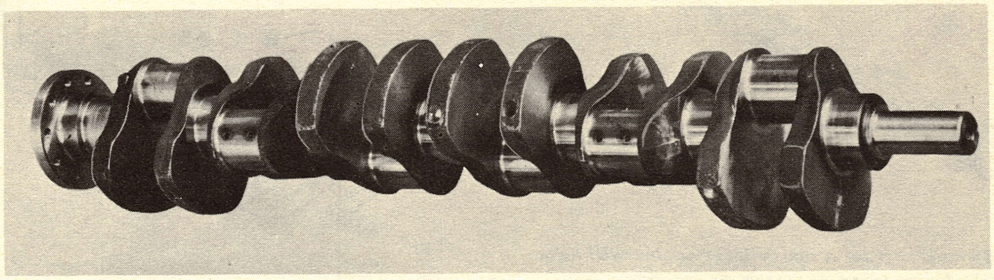
To stiffen engine block and crankcase castings, webs or ribs are often added to the casting at the points of greatest stress. In some cases the crankcase is extended below the center line of the crankshaft rather than having the oil pan surface in the same plane as the crankshaft. See Fig. 4-9.

While the metal used for these castings is ordinarily termed "cast iron" or "aluminum" as the case might be, the terminology is rather



4-9. *The line A-A is on a plane with the center of the crankshaft while the crankcase extends to the line B-B. Note stiffening webs or ribs at 0-0-0-0 in crankcase.*

loose because these metals in most cases are alloys. In the case of cast iron, small amounts of chromium, molybdenum or other metals may be added. In the case of aluminum castings, it is customary to add other materials to create an alloy which along with heat and chemical treatment increases the strength and wear resisting ability of the metal. In some cases sleeves are inserted in the cylinder blocks to resist wear, minimize distortion, etc. These sleeves will be discussed later.

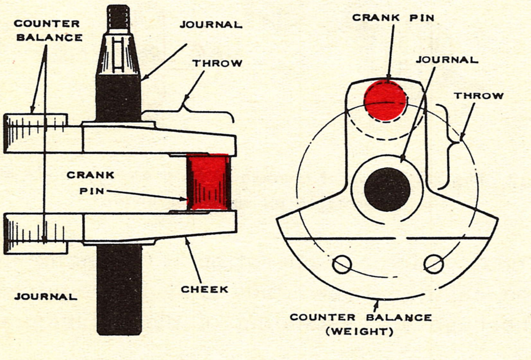


4-10. This typical crankshaft is for a six cylinder engine and has a main bearing journal between each of the cylinders.

ENGINE CRANKSHAFTS

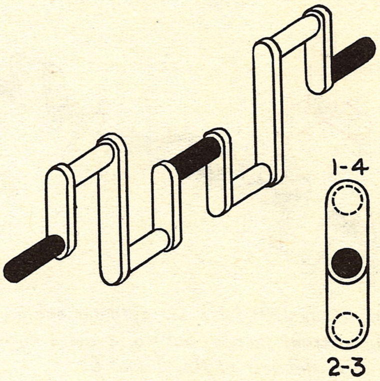
The engine crankshaft is often regarded as the "backbone" of the engine. It serves to change the reciprocating motion of the piston into rotary motion and handles the entire power output. It revolves in bearings located in the engine crankcase, must be free to revolve with as little friction as possible, yet must not have any appreciable looseness in the bearings.

For these reasons, the crankshaft is large in diameter, very accurately machined, and the bearings which support it are of generous size and length. The number of bearings used will depend upon the number of cylinders in the engine, and the design of the engine. By locating a main bearing journal between each cylinder, it is possible to use a lighter crankshaft than if two cylinders are placed between each main bearing journal. See Fig. 4-10.



4-11. Single throw crankshaft as used in single cylinder engine. Main bearing journals are in solid black, connecting rod journals in color.

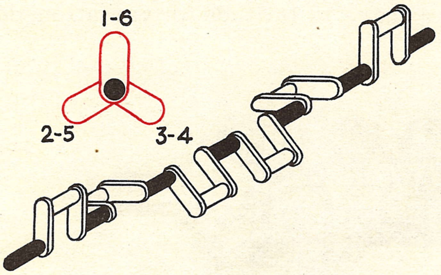
While engine crankshafts are in general quite similar there is latitude for variation, depending upon the design of the engine. A single-cylinder engine will have one throw on the crankshaft, as shown in Fig. 4-11. A two-cylinder engine will have two throws spaced 180 deg. apart. A three-cylinder engine will have three throws spaced 120 deg. apart. A four-cylinder engine will normally have cylinders 1 and 4 on the same side, and cylinders 2 and 3 on the other side, 180 deg. apart as shown in Fig. 4-12.



4-12. A four cylinder crankshaft will normally have the throws spaced 180 degs. apart with cylinders 1 and 4 on the same side. Some V-8s use a similar construction.

SIX CYLINDER CRANKSHAFTS

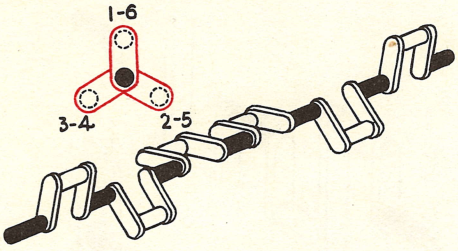
A six cylinder engine may have a left-hand crankshaft or a right-hand crankshaft, depending on the firing order of the cylinders. (Firing orders will be covered later). The crank throws are spaced 120 deg. apart in both cases as shown in Fig. 4-13, and cylinders 1 and 6 are on the same side in each case. Likewise, cylinders 2 and 5 are in the same plane, and cylinders 3 and 4 are in the same plane. On the right-hand crankshaft, cylinders 3 and 4 are to the right of the No. 1 crank throw, while on the left-hand crankshaft, cylinders 3 and 4 are on the left side of the No. 1 crank throw. See Fig. 4-14.



4-13. A right hand crankshaft for a six cylinder engine will have the cranks arranged as shown herewith.

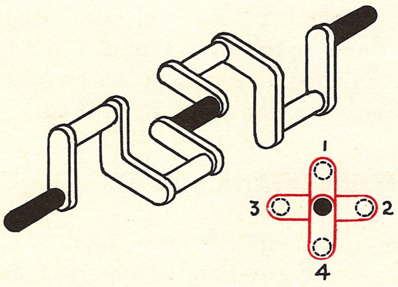
EIGHT CYLINDER CRANKSHAFTS

An eight cylinder V-type engine normally has a four-throw crankshaft with two cylinders attached to each throw. An in-line eight will have eight throws on the crankshaft.



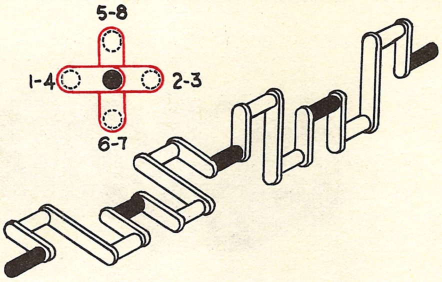
4-14. A left hand crankshaft for a six cylinder engine will have the same spacing of crank throws, but No. 3 and 4 throws will be to the left of No. 1 and 6.

In the V-8, variation of the location of the crank pins is possible. In one case, all four throws may be in the same plane, two on each side of the crankshaft, the same as a four-cylinder crankshaft, or the throws may be in two planes each 90 deg. apart as shown in Fig. 4-15.



4-15. While normally a V-8 crankshaft has the throws arranged the same as a four cylinder engine, a variation is possible as shown herewith.

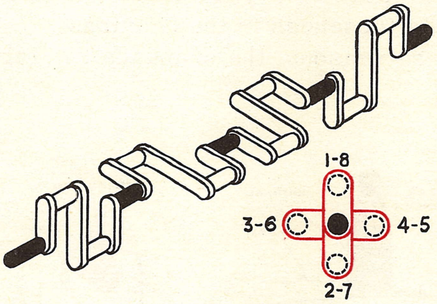
Variation is also possible in the in-line eight. One crankshaft is known as the 4-4 type, and the construction may be obtained by placing two four-cylinder crankshafts end to end with the crank arms of one crankshaft in a horizontal position, and the crank arms of the other in a vertical position as shown in Fig. 4-16.



4-16. A straight eight crankshaft of the 4-4 type resembles two four cylinder crankshafts connected end to end.

The other design is known as the 2-4-2 type, and may be obtained by sawing one four-cylinder crankshaft in two in the middle, placing half of it on each end of the other four cylinder crankshaft. In this case, the two crank arms on each end would be at right angles to the center four crank arms. See Fig. 4-17.

The foregoing covers in brief form the basic construction and operation of the major units of the engine. Some study may be required for a thorough understanding of these fundamentals.



4-17. The 2-4-2 type of crankshaft for a straight eight engine is arranged as shown herewith.

This complete understanding is essential in order to be able to grasp the details of operation and service procedures that are to follow. It will be found that the difference between poor work and truly expert work is that the expert understands WHY something needs to be done, as well as WHAT to do, and HOW to do it.

QUIZ - ENGINE FUNDAMENTALS

Write answers on separate sheet of paper. DO NOT write in this book.

1-All automobiles have either six or eight cylinders. True---False---.

2-The majority of automobile engines are of the water cooled type. True---False---.

3-Is a "flat" engine the same as an "in-line" engine? Yes---No---.

4-Name the largest single part of the engine.

5-Do all reciprocating engines have a crankshaft? Yes---No---.

6-List in proper sequence the events that occur in an engine cylinder during one cycle of operation.

7-A "valve" and a "port" are the same thing. True---False---.

8-How does the mixture get into the cylinder?

9-The "I head," "valve-in-head," and "overhead valve," engines are identical. True---False---.

10-How is the explosive mixture in the cylinder ignited?

11-What is the basic difference between a four-cycle engine and a two-cycle engine?

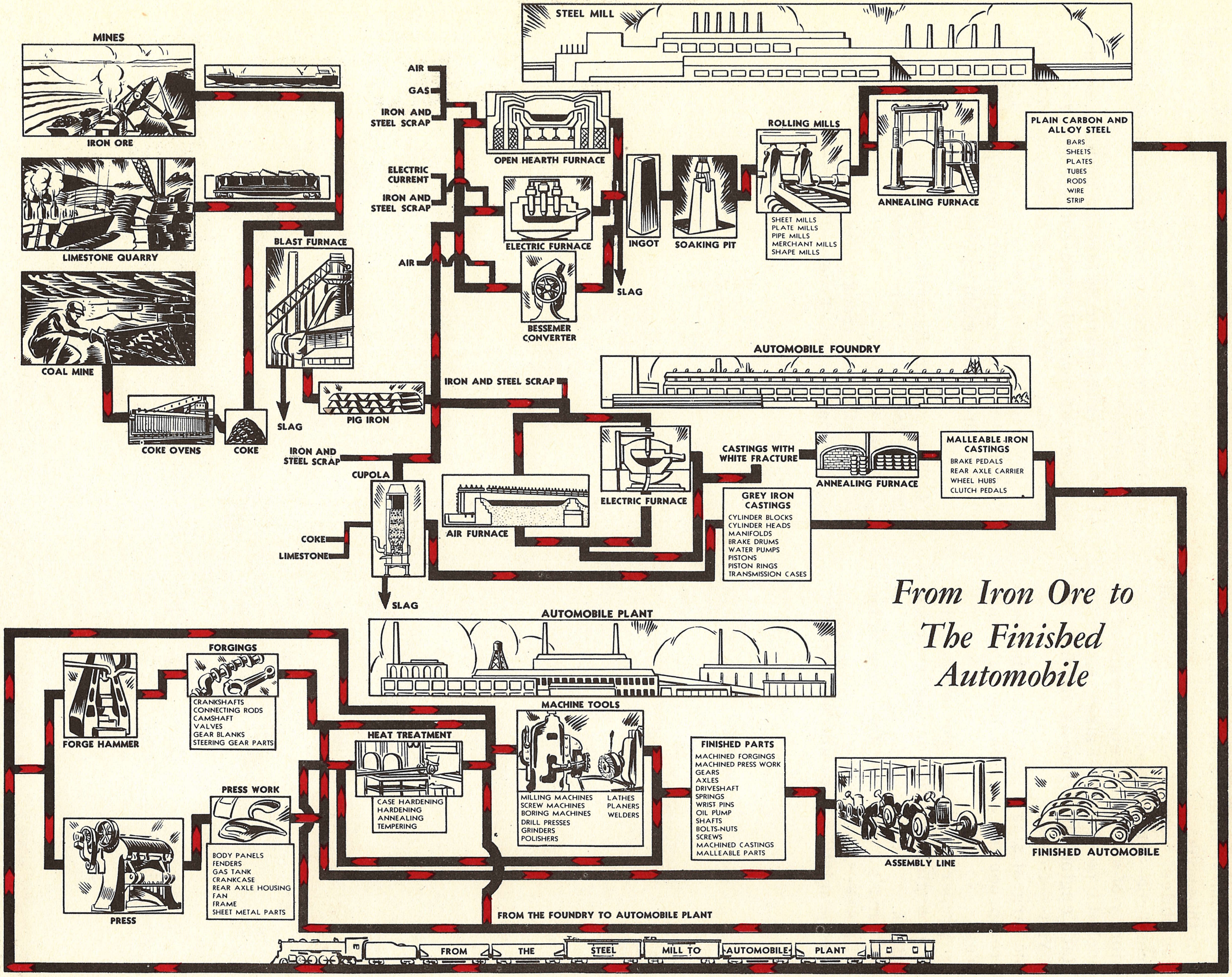
12-How many "throws" are on the crankshaft of a V-eight engine? Two---, Four---, Eight---.

13-Could two four-cylinder crankshafts be used for an in-line eight cylinder engine? Yes---No---.

14-What causes distortion of engine blocks?

15-All four cylinder crankshafts are alike. True---False---.

16-Six cylinder crankshafts may be of more than one design. True---False---.


MINES
IRON ORE
LIMESTONE QUARRY
COAL MINE
COKE OVENS
COKE
BLAST FURNACE
SLAG
PIG IRON
AIR
GAS
IRON AND STEEL SCRAP
ELECTRIC CURRENT
IRON AND STEEL SCRAP
AIR
STEEL MILL
OPEN HEARTH FURNACE
ELECTRIC FURNACE
BESSEMER CONVERTER
SLAG
INGOT
SOAKING PIT
ROLLING MILLS
SHEET MILLS
PLATE MILLS
PIPE MILLS
MERCHANT MILLS
SHAPE MILLS
ANNEALING FURNACE
PLAIN CARBON AND ALLOY STEEL
BARS
SHEETS
PLATES
TUBES
RODS
WIRE
STRIP
AUTOMOBILE FOUNDRY
IRON AND STEEL SCRAP
IRON AND STEEL SCRAP
CUPOLA
COKE
LIMESTONE
SLAG
AIR FURNACE
ELECTRIC FURNACE
CASTINGS WITH WHITE FRACTURE
ANNEALING FURNACE
MALLEABLE IRON CASTINGS
BRAKE PEDALS
REAR AXLE CARRIER
WHEEL HUBS
CLUTCH PEDALS
GREY IRON CASTINGS
CYLINDER BLOCKS
CYLINDER HEADS
MANIFOLDS
BRAKE DRUMS
WATER PUMPS
PISTONS
PISTON RINGS
TRANSMISSION CASES
From Iron Ore to The Finished Automobile
AUTOMOBILE PLANT
FORGINGS
FORGE HAMMER
CRANKSHAFTS
CONNECTING RODS
CAMSHAFT
VALVES
GEAR BLANKS
STEERING GEAR PARTS
HEAT TREATMENT
CASE HARDENING
HARDENING
ANNEALING
TEMPERING
MACHINE TOOLS
MILLING MACHINES
SCREW MACHINES
BORING MACHINES
DRILL PRESSES
GRINDERS
POLISHERS
LATHES
PLANERS
WELDERS
FINISHED PARTS
MACHINED FORGINGS
MACHINED PRESS WORK
GEARS
AXLES
DRIVESHAFT
SPRINGS
WRIST PINS
OIL PUMP
SHAFTS
BOLTS-NUTS
SCREWS
MACHINED CASTINGS
MALLEABLE PARTS
PRESS WORK
PRESS
BODY PANELS
FENDERS
GAS TANK
CRANKCASE
REAR AXLE HOUSING
FAN
FRAME
SHEET METAL PARTS
ASSEMBLY LINE
FINISHED AUTOMOBILE
FROM THE FOUNDRY TO AUTOMOBILE PLANT
FROM THE STEEL MILL TO AUTOMOBILE PLANT

From iron ore to the finished automobile.

ENGINE CONSTRUCTION

Many things are demanded of an engine used to propel an automobile. Some of them are:

A. Power to climb steep grades.
B. Speed to go as fast as desired.
C. Economy in the use of fuel and oil.
D. Flexibility for ease of handling.
E. Quietness in operation.
F. Freedom from frequent adjustments.
G. Reliability to go anywhere--any time.

Some of these requirements are conflicting. For example; any amount of power can be had from an engine of sufficient size, but a super-size engine is not economical to operate. Other conflicts exist, so all automobile engines are a compromise in several ways, in order to obtain the most desirable combination of performance characteristics.

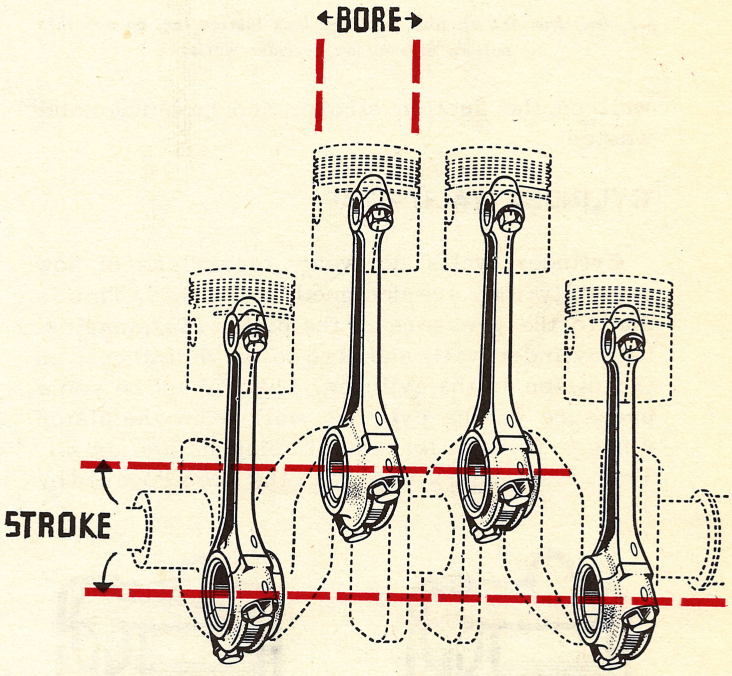
The size of an engine is determined by the bore, stroke and number of cylinders. The bore is the diameter of the cylinders; the stroke is the length of piston travel. See Fig. 5-1. The bore area multiplied by the stroke will give the displacement of one cylinder; which multiplied by the number of cylinders, will give the engine displacement or size.

Size alone however is not a definite measure of the power developed by the engine. Many other things need to be taken into consideration. Some of them are:

1. Engine rotating speed.
2. Compression ratio.
3. Valve size, lift and timing.
4. Internal engine friction.
5. Mechanical condition of parts.

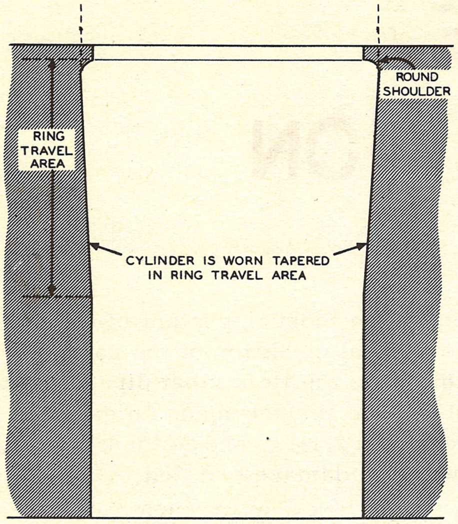
Many other things enter into this, which will be dealt with later in detail. It might seem that items 1, 2, 3 and 4 are inbuilt and not subject to alteration by service procedures. However, each can be altered by the mechanic and must be understood by him.

Possibly the most important of these items is the mechanical condition of the parts and units. Certainly it is the item most directly under the control of the service man. An example of this is the cylinders, rings and pistons. If an engine is badly worn or damaged so that there is little or no compression in the cylinders, the mechanic can do little in any direction until compression has been restored.



5-1. While the diameter of the cylinder determines the bore of an engine, the length of the crank arm determines the distance the piston will travel.

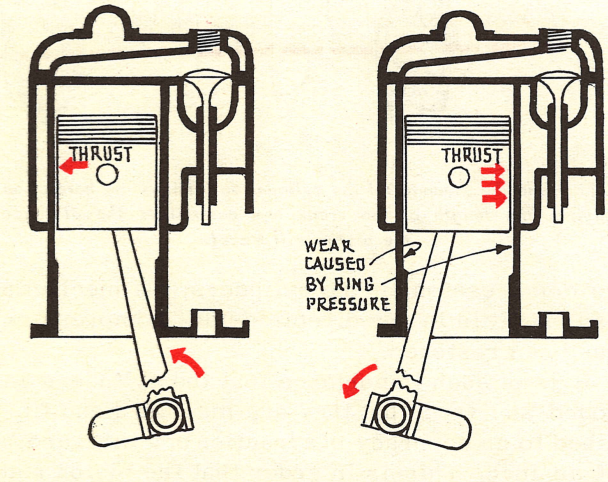
It is of such importance that the cylinders be round and true that they are machined and finished to an accuracy of a fraction of a thousandth of an inch. This is in order that the piston and rings, which are finished with equal accuracy, will have a true mating surface. Otherwise the compression may leak between the pistons and cylinders on the power and compression strokes, and little power would be developed. Also the oil might leak through between piston and cylinder wall on the suction stroke, and be burned and wasted.



5-2. Grit from the air plus heat and less lubrication, causes this pattern of wear on cylinder walls.

CYLINDER WALL WEAR

Cylinder walls do wear regardless of how carefully they are designed or finished. This is due to the pressure of the piston rings against the cylinder wall, and also to the side thrust on the piston in the cylinder. There must be some pressure on the cylinder wall from the piston rings to prevent leakage of compression and oil. This wear occurs mostly in the area covered by the piston rings as they travel up and down in the cylinder. The cylinders wear to a taper as shown in Fig. 5-2.



5-3. The side thrust on the piston is greater on the explosion stroke than on the compression stroke due to the greater pressures on the piston head.

The cylinders also wear out-of-round because of the side thrust of the pistons which is due to the angular relationship between the connecting rod and crankshaft. See Fig. 5-3. Pressures exerted on the piston are much greater on the power stroke than on the other strokes. As a consequence, the cylinder wears most on the power thrust side and becomes out-of-round.

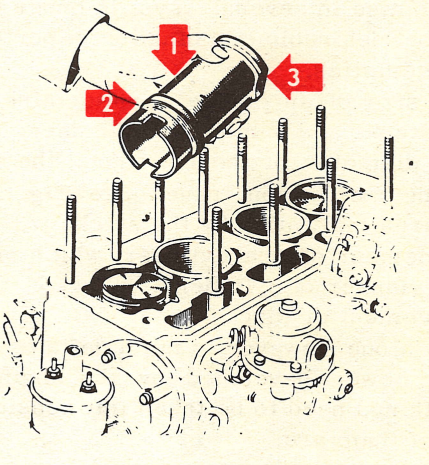
It will be seen from Fig. 5-2 that wear at the top of the ring travel is greater than at the bottom. This tapered wear is due to two conditions:

A. The cylinder and piston are hotter and are exposed to more grit at the top than at the bottom. Therefore, wear is accelerated.

B. There is more oil at the bottom ring and in the bottom of the cylinder than in the top. This tends to reduce friction and wear.

This cylinder and ring wear will be given additional consideration later in this text.

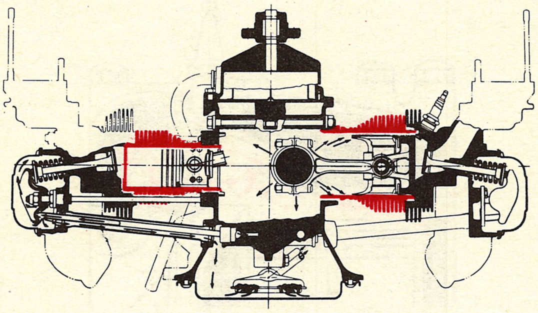
In some engines the cylinders are fitted with sleeves upon the inner surface of which the piston rings bear. These sleeves are of two types "dry" and "wet." The dry type is simply a sleeve or barrel which is pressed into an oversize bore in the cylinder block. The wet type is a cylinder barrel which replaces the cylinder wall and the cooling water circulates in contact with the outside of this barrel. In this case, a sealing gasket is required at both ends of the cylinder barrel. See Fig. 5-4.



5-4. Arrow 1--Inserted wet sleeve. Arrow 2--Bottom sealing gasket. Arrow 3--Top sealing surface for head gasket.

Air cooled engines quite often use a barrel-type cylinder which is complete in itself. See Fig. 5-5.

There is a certain service advantage to either the wet or dry type of cylinder sleeve, or the separate barrel type cylinder in some cases. If one cylinder wall becomes damaged, it may be more economical to replace the sleeve or barrel, than to rebore the cylinder and fit oversize pistons and rings. Furthermore, if the cylinder had to be oversized very much the engine would be out of balance unless all the cylinders were oversized the same.



5-5. The air cooled Corvair engine has three cylinders on each side of the crankshaft. The crankcase and cylinder heads are of aluminum alloy, with pockets or recesses in each to receive the cast iron cylinder barrels.

Another method of reducing the wear on the inside of the cylinder, is to chrome plate the surface where the rings bear. It is customary in such cases to provide very small indentations in the plated surface to encourage the retention of an oil film.

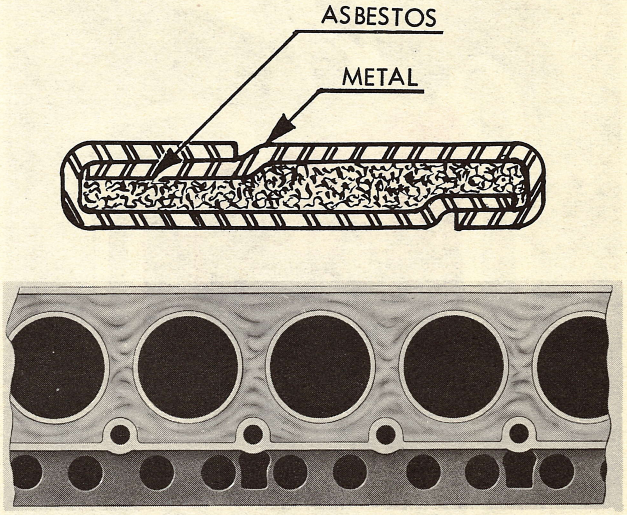
CYLINDER HEAD GASKETS

The cylinder head is held to the cylinder block or crankcase casting by bolts or studs, and a gasket is placed between the head and block to maintain a water-tight and gas-tight seal. These gaskets may be in the form of a metal sheet soft enough to deform as required, but are usually made like a sandwich; two thin plates of soft metal with a reinforced asbestos filling between them. See Fig. 5-6.

As the cooling water must circulate between the head and block of a water-cooled engine, holes are punched in this gasket to coincide with the matched openings in the head and block. If a poorly made gasket is used, or an improper model gasket used, the flow of cooling water between the head and block will be restricted and troublesome hot spots are liable to result.

On some engines, the gaskets are so nearly uniform, particularly on V-type engines, that they can be turned over, or end for end and will fit the retaining studs and combustion chamber, but stop off water circulation at one end. It is therefore important to make sure that the correct gasket is used and that it is correctly installed to avoid possible restriction or closing of water circulating holes.

The exceptions to the foregoing are a few isolated cases where manufacturers have issued service gaskets with a few blind or restricted holes to slow down the circulation of water at some certain spot. In a few other cases, the service gasket has a few additional holes and the manufacturer recommends drilling additional holes in the head and block to increase the circulation of cooling water at some point. These cases are rare and seldom encountered.



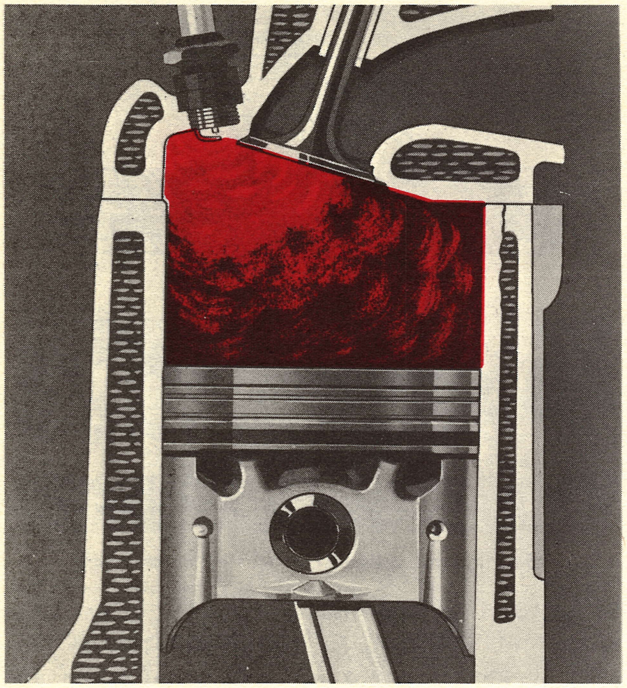
5-6. Typical cylinder head gasket construction.

COMBUSTION CHAMBER

The combustion chamber is the space within the cylinder, above the piston, where the burning of the gas occurs. See Fig. 5-7. Since the early days of the Industry, research has continued and is still continuing, perhaps more rapid than ever before, on the design characteristics of the combustion chamber itself. This text is not an engineering design book but is intended as a service text. We will therefore not get into combustion chamber design any deeper than is necessary for our purpose.

The trend in design has been, and is, to concentrate as much of the expansion force as possible on the head of the piston and avoid dissipation of the expansive force in directions that do not produce power. It may be seen by reference to preceding illustrations of cylinder types that the overhead valve type comes nearer to accomplishing this objective than any of the others.

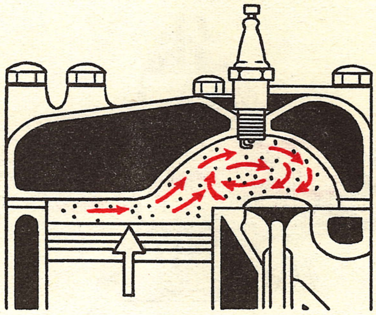
Another trend is toward the creation and control of turbulence or movement of the air and gasoline mixture within the cylinder to create a more uniform and better mixture of the gasoline and air. One design was developed by an engineer named Ricardo and was used extensively in L head engines. The principle of this design is shown in Fig. 5-8. In the case of extremely high compression engines, some very involved shapes have been used for cylinder heads and pistons. Such designs are characteristic of Diesel engines which will be studied as this text progresses.



5-7. *Combustion chambers vary widely in shape, and are sometimes partially in the cylinder, piston head and valve head as well as the cylinder head.*

It has long been recognized that the more the explosive mixture is compressed within the cylinder before it is ignited, the more power will be developed by the explosion stroke. A limiting factor other than the strength of the engine parts is imposed, however, by the characteristics of the fuel used. One of these characteristics is the tendency of the fuel to "ping" or "knock" as the compression pressure is raised. Much research and study have been expended on this phenomenon which is known as detonation. This is ordinarily attributed to irregular and too rapid expansion or explosion of the gasoline and air mixture. The noise comes from vibration of the walls of the combustion chamber.

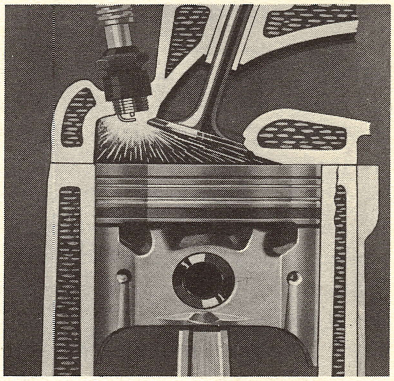
The material of which the combustion chamber is made, and the efficiency of the cooling system also have a distinct bearing on the compression ratio that can be used in a given engine. For example, aluminum cylinder heads and aluminum pistons can operate at higher compression ratios than cast iron or steel. One reason for this is perhaps that the heat of combustion is dissipated more rapidly to the cooling water or air due to the superior heat conducting ability of aluminum.



5-8. *The shape of the combustion chamber has much to do with the proper mixing of the gasoline and air to obtain maximum benefit from the combustion.*

ENGINE PISTONS

Engine pistons serve several purposes: they transmit the force of the explosion to the crankshaft through the connecting rod; they act as a guide for the upper end of the connecting rod; they also serve as a carrier for the piston rings used to seal the piston in the cylinder. See Fig. 5-9.



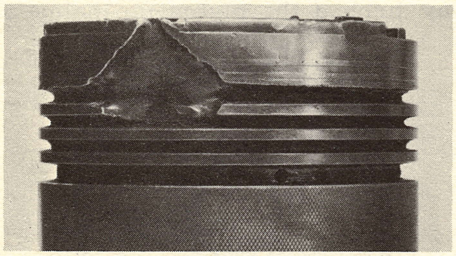
5-9. *This particular piston is of the aluminum "skeleton" type and is used with an aluminum connecting rod.*

Pistons operate under exceedingly difficult mechanical and thermal (heat) conditions, and must therefore be made and installed with the utmost care. They must be strong enough to stand the force of the explosion, and yet be as light as possible to avoid excessive inertia forces when their direction of travel is reversed twice each revolution. They must be able to withstand the heat from the burning gas, plus the heat generated by friction. As they must slide freely within the cylinder, they cannot be fitted too tightly. If too loosely fitted in the cylinder, they will knock and rattle.

PISTON MATERIALS

Cast iron or semi-steel has been used extensively as a piston material. It is strong enough for the stresses imposed; has a melting point above the cylinder operating temperature; expands at the same rate as cast iron cylinders, and does not generate excessive friction when properly lubricated. The principal objection is that of weight. This objection has increased in importance as engine speeds have been increased.

Aluminum alloy is also used as a material for pistons. It is lighter than cast iron, is readily cast and machined, and does not generate excessive friction in the cylinder. Aluminum expands more rapidly than cast iron when subjected to the heat of operation, and also has a much lower melting point. In material and design, the aluminum piston has been developed to a point where its advantages apparently outweigh its disadvantages, because it is almost universally used in automobile engines.



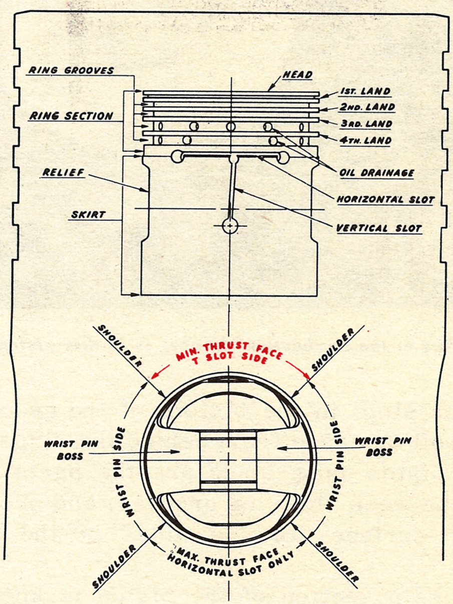
5-10. This is typical of piston damage when the top of the piston becomes overheated.

The lighter weight means less inertia for the reciprocating parts and thus higher speed for the engine along with better acceleration. This lessened inertia also decreases bearing loads at high speeds and reduces side thrust on the cylinder walls. Due to the greater heat conductivity of aluminum, the piston head runs cooler and in general, it is possible to use higher compression ratios.

Early aluminum pistons were noisy because they had to be fitted in the cylinder with considerably more clearance than cast iron pistons. This resulted in piston slap and rattle when the engine was cold, and until the piston expanded in the cylinder. This difficulty has been largely overcome by designing the piston skirt so it is flexible, and by alloying the material of which it is made.

Aluminum pistons possess the desirable characteristic of conducting the heat away from the combustion chamber more rapidly than cast iron, but they also melt at a much lower temperature. Aluminum pistons seldom melt entirely, but their strength decreases rapidly as the temperature increases. In many cases of stuck or broken rings, the top edge of the piston or the aluminum lands between the rings, may soften and melt or be blown away by the hot gas as shown in Fig. 5-10.

Severe and continued detonation is also responsible for broken piston heads and wedged piston rings. The aluminum is said to become soft and plastic enough when overheated, to allow the ring grooves to deform. The strength of aluminum pistons can be increased by alloying the aluminum with other metals and also by heat treatment processes. Some of the materials added to the aluminum are copper, magnesium, nickel, silicon, etc.

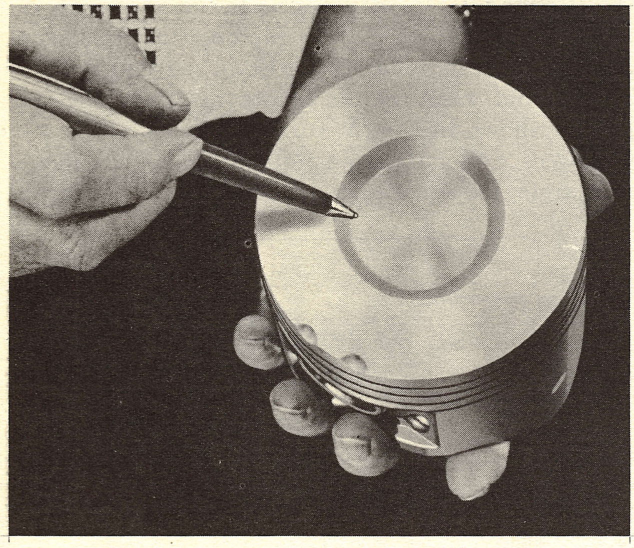


5-11. Note that the T slot is on the minor thrust side. The major thrust side has horizontal slot only.

PISTON CONSTRUCTION

The piston head or "crown," Fig. 5-11, is the top surface against which the explosive force is exerted. It may be flat, concave, convex, or a great variety of shapes to promote turbulence or help control combustion. See Fig. 5-12. A narrow groove is sometimes cut into the piston above the top ring to serve as a "heat dam" to reduce the amount of heat reaching the top ring.

The piston rings which are carried in the ring grooves are of two basic types: "compression" rings and "oil control" rings. Both types are made in a wide variety of designs. The upper ring or rings are to prevent compression leakage, and the lower ring or rings are to control oil. The lower groove or grooves often have holes or slots in the bottom of the grooves to permit oil drainage from behind the rings.



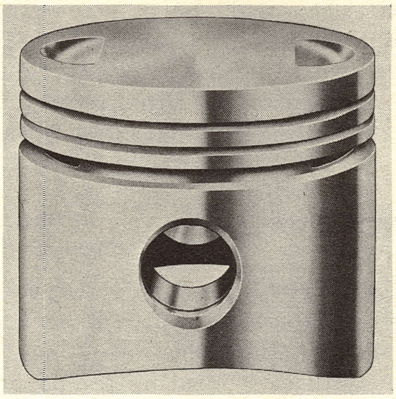
5-12a. Part of the combustion chamber is in this piston head.

The piston ring lands are the parts of the piston between the ring grooves, and provide a seating surface for the sides of the piston rings.

The main section of the piston is known as the skirt and forms a bearing area in contact with the cylinder wall which takes the thrust caused by the crankshaft as previously described. There is some thrust on both sides. The "major" thrust side is the side opposite the crank throw, as it goes down on the power stroke. The "minor" thrust is of course the other side, which is opposite the crank throw as the piston goes up on the compression stroke. Pistons are internally braced to make them as strong as possible. See Fig. 5-13.

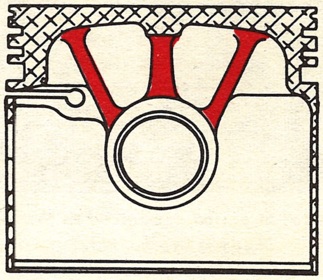
The piston or wrist pin hole in the piston bosses may also serve as a bearing for the piston pin, and may not be located in the exact middle of the piston. It may be placed as much as 1/16 in. to one side, in an effort to lessen the side thrust on the cylinder wall.

In some cases the piston skirt is extended downward on the thrust sides to form what is known as a "slipper" piston. This design may be seen in Figs. 5-9 and 5-12. The purpose of this design is to increase the area of piston contact with the cylinder walls on the thrust faces.



5-12b. Indentations in top are for valve head clearance.

Some pistons are also cut away, or partially cut away around the piston pin holes as may be seen in Figs. 5-9, 5-11, and 5-12a. This is known as a "relief" and is intended to provide additional clearance to avoid "seizing" if the piston should become overheated and expand excessively.

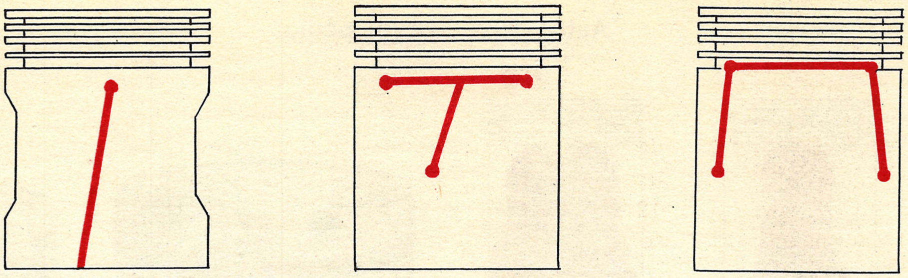


5-13. Ribs are cast into the inside of the piston to strengthen it between the crown and the piston boss.

PISTON DESIGN

Alloy pistons may have the skirts split in a variety of ways. Some typical piston slots are shown in Fig. 5-14. These slots are placed on the thrust sides to provide flexibility in the piston skirt. By this means the piston can be fitted more closely when cold and can expand when hot, without damage.

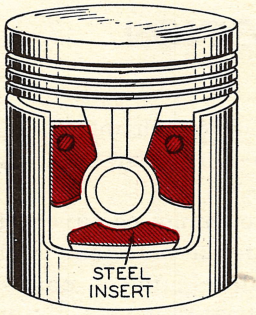
Other pistons are of the "strut" type as



5-14. Left. Aluminum pistons may have a diagonal slot cut through the skirt on the minor thrust side. Center. In some cases, a slot shaped something like a T is cut in the piston skirt. Right. Two slots may be connected by a third slot to form a U-shaped slot design.

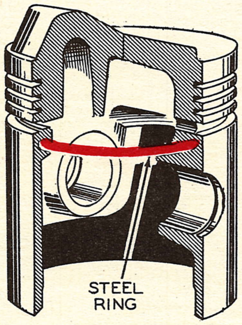
shown in Fig. 5-15. In this case, an alloy steel insert is cast into the aluminum piston to control the expansion of the aluminum, and thus maintain more constant clearance. Such pistons are usually skeleton like and do not contact the cylinder walls around the piston pin holes.

Still another design is known as the "steel belted" type and has a steel ring cast into the aluminum piston above the piston pin holes to help control expansion. See Fig. 5-16.

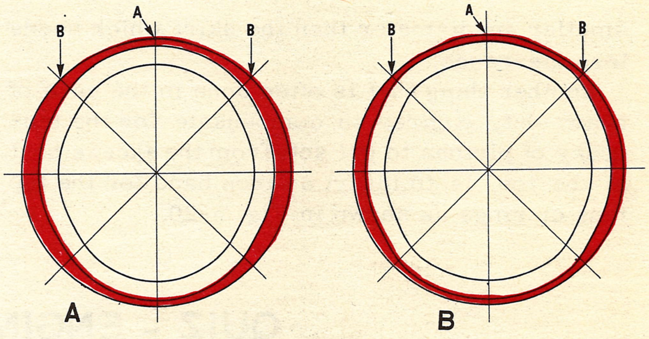


5-15. A steel insert may be cast into an aluminum piston to help control the expansion rate.

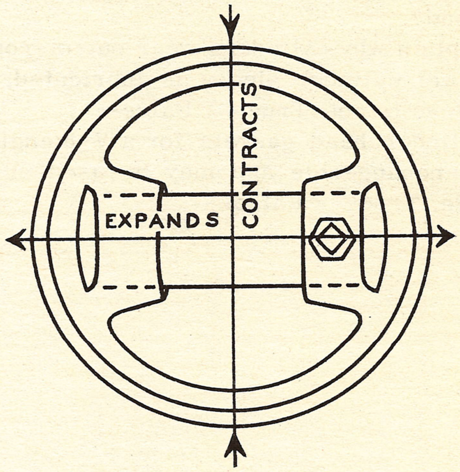
Most aluminum pistons are "cam-ground"--that is, they are purposely machined with the skirts oval as shown in Fig. 5-17. The reason for this is that while the skirts will be out-of-round when cold in such fashion that the thrust faces will have the greater diameter, the skirt will become more nearly round when the piston expands at operating temperature. See Fig. 5-18.



5-16. Instead of a vertical insert, a steel ring may be cast into the piston to help control the expansion.



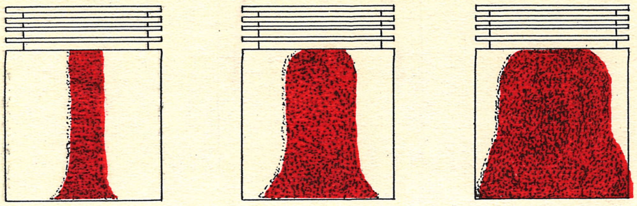
5-17. (A) When the piston is cold, there is also more clearance at the shoulders (B) than at (A). (Clearances are exaggerated for emphasis). (B) As the temperature of the piston increases, it becomes more nearly round and the clearance more nearly uniform.



5-18. Expansion of the piston occurs parallel with the piston pin.

In this case the piston contact surface is something like the pattern shown in Fig. 5-19.

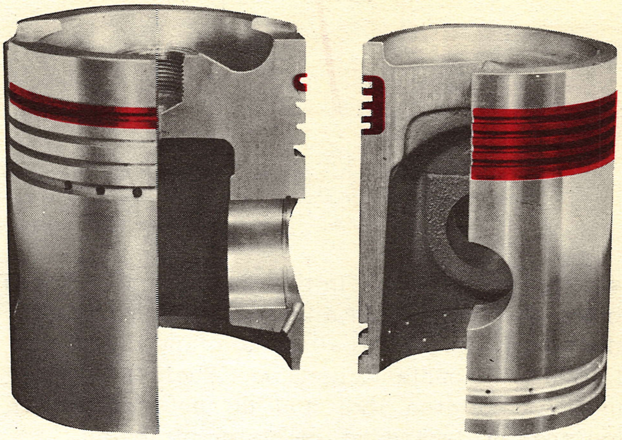
Pistons are also slightly tapered in many cases. The top of the piston runs much hotter than the bottom or skirt so the top is smaller in diameter. This is particularly true of the piston above the top ring. When the entire piston is not tapered, the top lands are at least



5-19. *As a cam ground piston expands, the pattern of contact with the cylinder wall progresses from the cold piston at left to the warm piston at right.*

smaller in diameter than the skirt which needs less clearance.

Another thing that is often done in the case of heavy-duty engines to compensate for the tendency of pistons to get soft from the excess heat at the top, is to insert an iron band for the top ring or rings as shown in Fig. 5-20.



5-20. *Inserted iron bands are sometimes used in heavy duty pistons to strengthen the ring grooves.*

QUIZ - ENGINE CONSTRUCTION

1-The power of an automobile engine is determined by the number of cylinders. True--- False---.

2-The stroke of the engine is determined by the: length of the cylinder---, crankshaft throw ---, displacement of the cylinder---.

3-How can the displacement of an engine be found?

4-Explain why cylinders wear out-of-round.

5-A wet cylinder sleeve is lubricated, a dry sleeve is not. True--- False---.

6-Cylinder head gaskets for a V-8 engine are interchangeable and may be used on either side. True--- False---.

7-The combustion chamber is usually: above the piston---, below the piston---, in the crankcase---.

8-Name three things required of the piston.

9-Which material is used most for pistons: steel---, aluminum---, cast iron---?

10-What is a heat dam in a piston?

11-Which side of the piston is the major thrust side?

12-What is meant by piston relief?

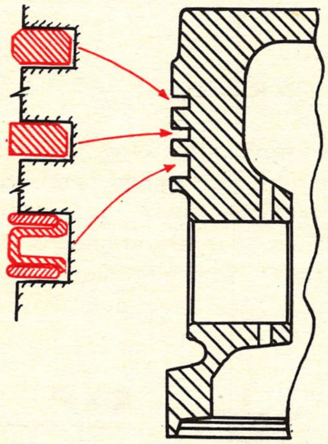
13-Pistons are slotted so that they can be more readily inserted in the cylinders. True--- False---.

14-Describe a cam-ground piston.

ENGINE
PISTON RINGS

Piston rings have been designed with such a multitude of variations as to be almost unbelievable. Originally they were a simple split ring made of cast iron. As engine power output has constantly increased and oiling requirements have steadily become more complicated, more and more has been demanded of piston rings.

Modern piston rings are made of steel as well as cast iron and are often of multiple sections instead of a single piece. They are often quite complicated in design, are heat treated in various ways and plated with other metals. Furthermore there are two distinct classifications: compression rings and oil control rings. A typical piston ring installation is shown in Fig. 6-1.

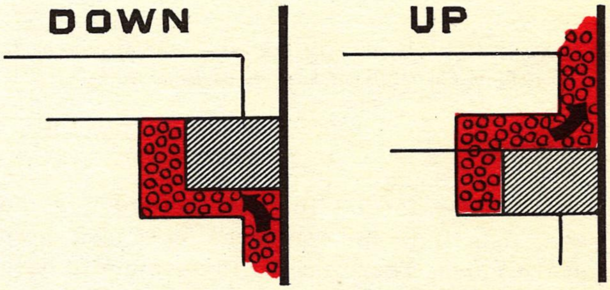


6-1. This cross section shows two compression rings in the upper grooves, and an oil control ring in the lower groove.

Piston rings would not present much of a problem if cylinders and pistons did not expand, distort out-of-round, and warp when at operating temperatures. But they DO expand and may also distort and warp, so the rings must be capable of conforming to these changing conditions. Furthermore, the ring itself is exposed to heat and to alternating pressure and vacuum. It is expected to prevent the passage of pressure in one direction and to control the flow of oil in the other direction.

PISTON RING BLOW-BY

The compression pressure and explosion pressure can go past the ring in several ways.



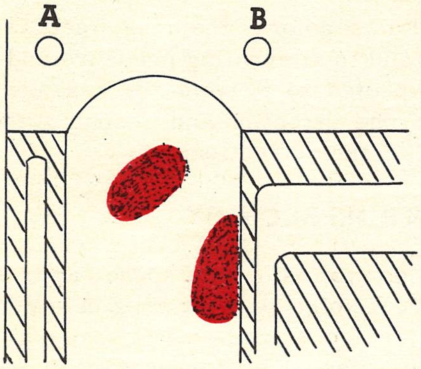
6-2. Oil can creep around in back of the rings to find its way into the combustion chamber, and gases can creep down into the crankcase from the combustion chamber in a similar manner, but in the opposite direction.

This is known as "blow-by." The pressure can go through the ring gap which changes in width according to the expansion and contraction of the cylinder and ring. If it were fitted so precisely that the ring ends touched to seal the gap, it would score the cylinder when the ring expanded from the heat of operation.

Blow-by can also occur by going behind the ring as shown in Fig. 6-2. If the ring were fitted tightly enough sidewise in the groove to avoid possible leakage, there would be danger of sticking when the piston and rings expand.

Blow-by is a serious problem when the cylinder walls distort out-of-round when at operating temperature. This can be caused by improper cylinder or cylinder head design, improper cooling or unequal tightening of adjacent bolts. This distortion may occur in more than one spot on the cylinder wall and the different spots are often of different size and shape. See Fig. 6-3.

In the same ways that compression leaks down past the ring, oil can also pass upward into the cylinder and the result is known as "oil-pumping." This causes fouling of the spark plugs, excessive deposits of carbon in the combustion chamber, and smoking at the exhaust as well as waste of oil.



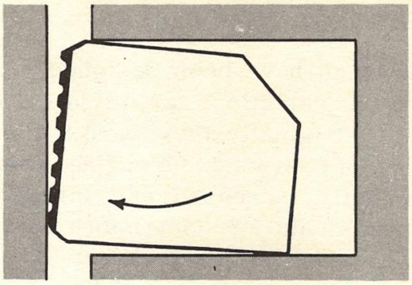
6-3. Distortion of cylinder walls can cause the cylinders to be out-of-round or to distort in spots as indicated here.

OIL-PUMPING

It is easier for oil to pass upward in some cases, than it is for compression to leak down past the rings. Therefore, it is possible to have an engine with good compression and power, which is also an oil-pumper. The oil might act to seal excessive side clearance in the ring grooves, and prevent leaks of compression. At the same time, the alternating vacuum and pressure in the cylinder may cause the ring to act as a pump. See Fig. 6-4.

This condition is aggravated if the walls of the ring grooves, and the sides of the rings, are not flat and true. The volume of leakage past the back of the ring can be much greater than through the tiny gap at the ends of the ring.

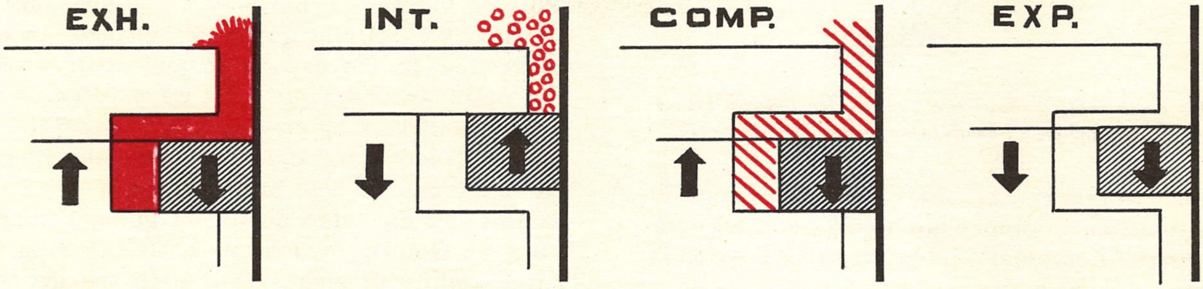
It may be seen from the foregoing that great care is required in reconditioning cylinders to make sure that they are round and true when new rings are fitted. Equal care is required in selecting the new rings and fitting them to the pistons and cylinders. Many other things which enter into the matter will be considered in this text.



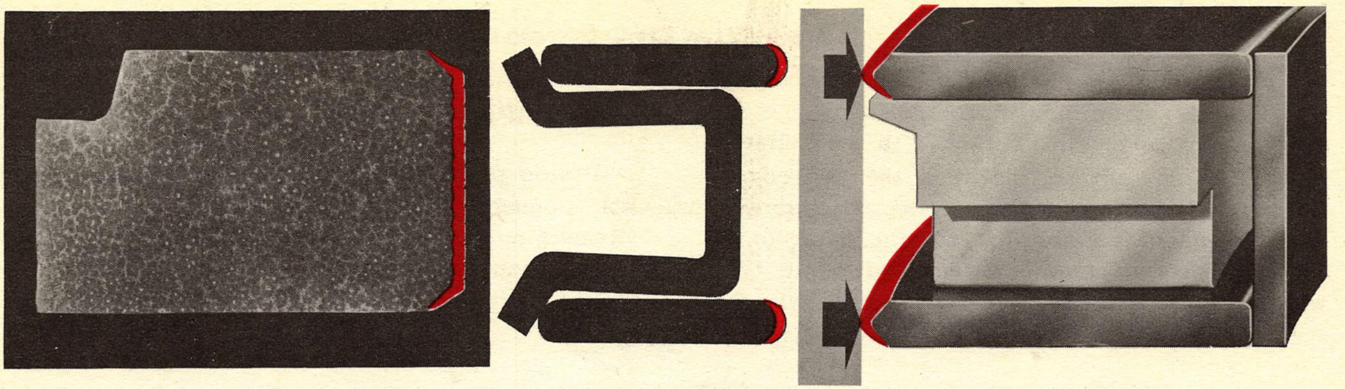
6-5. A ring beveled in this manner has a tendency to tilt in the ring groove.

COMPRESSION RINGS

The top compression ring is usually a plain ring, rectangular in cross section or with a groove cut into the inner top corner. See Fig. 6-5. Sometimes it is also chrome plated on the contact surface. See Fig. 6-6. Other designs are tapered on the face and may or may not



6-4. There must be some clearance between the ring and the bottom of the groove, and also on the sides of the ring. The result is that a ring can act as a pump in the manner shown. On the exhaust stroke, the exhaust gas tends to hold the rings in the bottom of the groove as the piston travels up. On the intake stroke, the vacuum in the combustion chamber tends to hold the ring against the top of the groove while the piston goes down. On the compression stroke, the pressure in the combustion chamber again tends to hold the ring against the bottom of the groove. On the explosion stroke, the expanding gases tend to push both piston and ring in the same direction, thus permitting the ring to float in the groove.

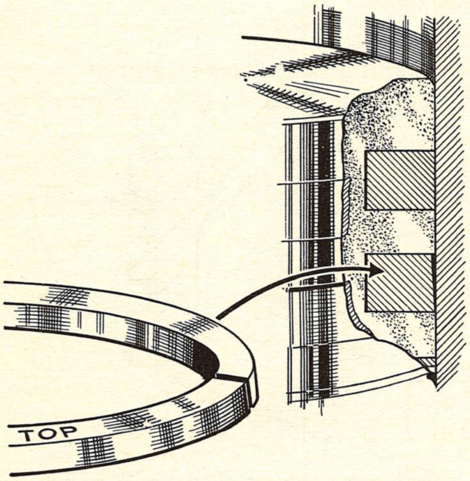


6-6. *Three different types of chrome plated piston rings.*

have an inside bevel or chrome plating.

The idea of the groove on the inside upper corner of the ring is to cause the ring to twist in the groove in such manner that the outside lower edge presses on the cylinder wall more tightly than the rest of the ring face. The tapered outer face does the same thing. In both cases, the limited area in contact with the cylinder wall offers a higher pressure at that point, to effect a better seal. Such rings must be installed right side up and are usually stamped "top" on the side to be installed on top. See Fig. 6-7.

The second ring is also usually a compression ring, but may be slightly different in design as it helps in oil control. This difference might be a groove cut into the inner or outer corner, which might be combined with a taper on either the inside or outside. A typical installation is shown in Fig. 6-8.

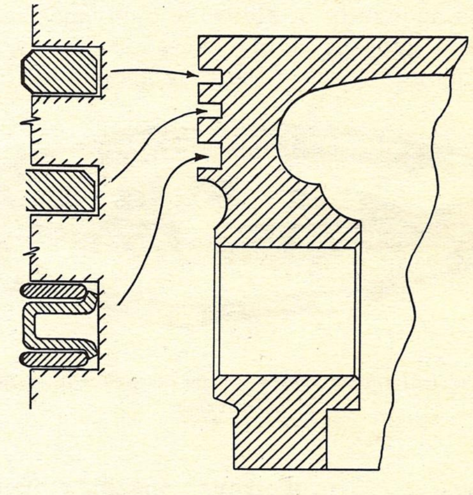


6-7. *Tapered rings are usually marked. If not, they should be installed as shown here.*

OIL CONTROL RINGS

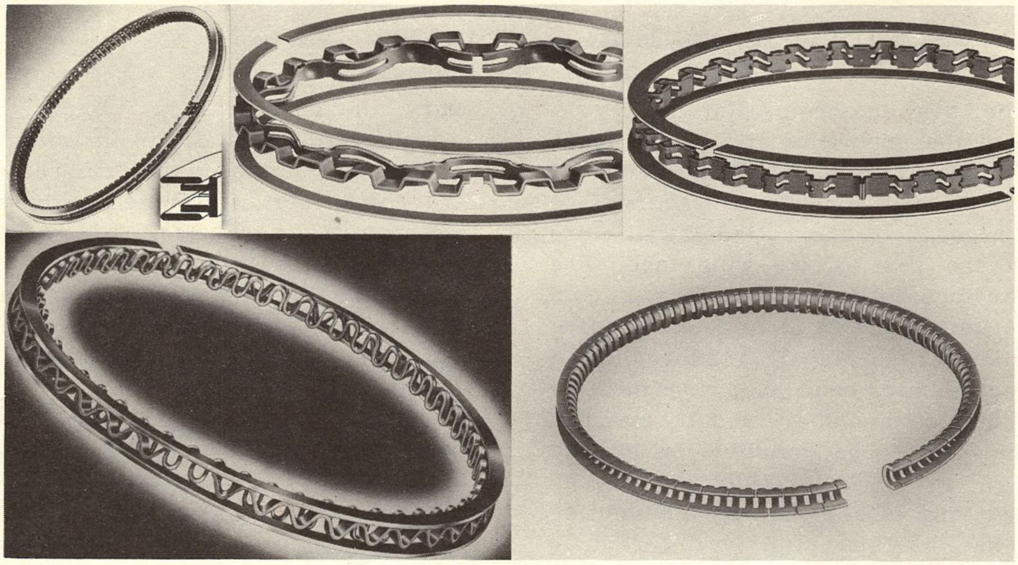
The third ring from the top, and the fourth if four are used, are of the oil-control type, and vary all the way from simple to extremely complicated types. Several varieties are shown in Fig. 6-9. In any case, it must be remembered that the oil scraped from the cylinder wall by the oil ring must have a free passage to the inside of the piston. For this reason, holes or slots are cut in the lower ring grooves. When an inner ring or expander is used these openings must be kept open if the oil ring is to function as intended. See Fig. 6-10.

Another typical ring installation is shown in Fig. 6-11. Note that the No. 1 ring, has a full face contact on the cylinder wall and the ring expansive pressure is therefore distributed over a wide area. Ring No. 2, is also a compression ring but has a narrower contact surface and therefore a higher pressure on that area, because the entire expansive force of the ring is concentrated on the narrow area in contact with the cylinder wall. The result is that the top ring will show less tendency to wear the cylinder in the driest and hottest part, and the second ring will seat more quickly to the cylinder wall even though it has more lubrication than the top ring.



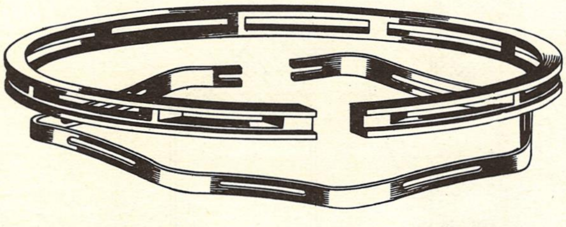
6-8. *In this installation, the top and bottom rings are chrome plated. The second ring is of the "twist" type.*

Ring No. 3, is an oil control ring and has two narrow edges in contact with the cylinder wall. Having slots cut between the two edges, the oil will be scraped from the cylinder wall into the channel or slots of the ring. Ring No. 4, in this case is of the extremely flexible type which follows closely the contour of the cylinder walls even when they are slightly out-of-round.



6-9. Oil control rings are made in wide variety.

In this connection, it is well to remember that the piston ring moves in the groove. Due to the constant reversing of direction of piston travel, and the necessity of sidewise clearance between ring and groove, it may be seen that the rings move up and down in the ring grooves as shown previously. A film of oil cushions this movement.



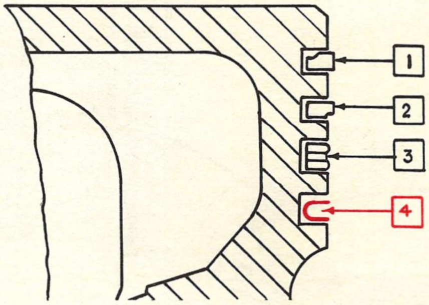
6-10. A typical slotted steel expander as used with a slotted oil control ring.

Likewise it will be understood that if the cylinder is worn tapered, the rings will expand and contract as they move up and down in a bore that is larger at one end than the other. Similarly if the cylinder is out-of-round in spots, the rings will be pumping in and out of the groove as they try to follow the cylinder wall.

PISTON PINS

Piston pins, also known as "wrist pins" are the connection between the upper end of the connecting rod and the piston. There are three main types:

A. Pins anchored in the piston with the bushing in the upper end of the connecting rod oscillating on the pin, Fig. 6-12.

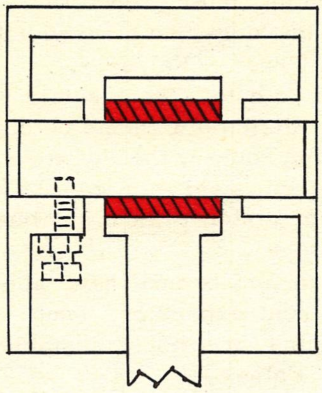


6-11. A typical piston ring installation with an extremely flexible oil control ring in the bottom groove.

B. Pins clamped in the rod with the pin oscillating in the piston, Fig. 6-13.

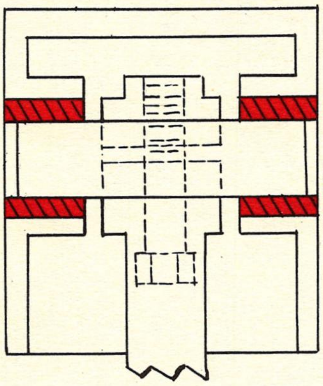
C. Pins which are full floating in both connecting rod and piston with lock rings or soft metal plugs in both piston bosses, to prevent endwise movement of the piston pin. See Fig. 6-14.

Other than the type of bearing and the provision for holding the pins in place, all three types are quite similar. They are ordinarily hollow steel pins, casehardened on the outside surface. They are subjected to extremely heavy loads and are not adjustable for wear. When worn, they must be replaced. As they have an oscillating motion in the bearing surface, rather than the high surface speed between the crankshaft and the connecting rod bearings, the steel pin can bear directly in the aluminum piston, or in bronze bushings in either cast iron or aluminum pistons, or a bronze bushing in the upper end of the connecting rod.



6-12. Where the pin is anchored in the piston, the bearing is located in the upper end of the connecting rod.

Other variations found in design include "needle" or roller bearings in hardened bushings, an "interference fit" in the connecting rod which requires the pin to be pressed into a hole slightly smaller than the pin. In the case of an aluminum connecting rod, there may be no bushing required.

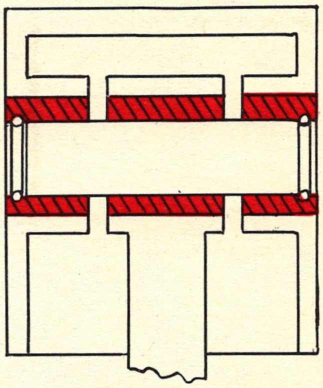


6-13. Where the piston pin is anchored in the connecting rod, there is a bearing in each of the piston bosses.

The proper size for a piston pin presents a problem. If the pin is large enough in diameter to provide a long wearing bearing surface, the reciprocating weight will be increased and the bearing loads correspondingly increased. If it is as small as permissible to hold down bearing loads, it will be smaller in diameter, and thus have less bearing surface to carry the load.

If the pin is fastened in the piston with a small screw, the assembly will be lighter than where a bolt is used in the connecting rod. However, if it is clamped in the rod, it will have double the bearing surface as there will be a bearing in each piston boss. If it floats in both piston and rod, it will have the greatest bearing surface along with the lightest weight. One problem with this construction is that if the locking ring or retaining plug should fail to stay in place, the pin will probably score the cylinder quickly and deeply.

One ever present complication is the fact that all three metals in contact; steel, bronze and aluminum, have a different rate of heat expansion. Obviously, being attached to the piston, the pins and bushings will run hot. In general, heat in any bearing promotes wear. Very little wear in a piston pin or bushing will create noise.



6-14. Where the pin is held in place by snap rings or plugs, the pin "floats" and bears in the piston bosses and also in the rod end. This illustration shows the principle involved, but actually the pin would bear directly in the piston bosses of an aluminum piston, and the retaining ring grooves would be cut into the piston.

It will then be understood that all piston pin designs are a compromise in some direction and none of them appear to be ideal. Of course the repairman can do little about the design of the engine parts, but if he has a thorough understanding of some of the problems involved in a case of this kind, he will be sure to do the best possible job and thus avoid having to do it over again. Fitting of piston pins will be explained in detail later herein.

QUIZ - ENGINE PISTON RINGS

1-Name two results of oil pumping.

2-Blow-by may be a serious problem after the engine warms up to operating temperature. True--- False---.

3-Do piston rings move up and down in the grooves? Yes--- No---.

4-Why must piston rings be flexible?

5-A piston ring may act as a pump. True--- False---.

6-Give two reasons for cylinder wall distortion.

7-Do piston rings move in and out in the grooves? Yes--- No---.

8-More oil leakage occurs at the ring gap than around behind the ring. True--- False---.

9-If an engine has good compression it will not pump oil. True--- False---.

10-Name four ways of holding the piston pin in place.

11-Describe an "interference fit."

12-Bronze bushings can be used with aluminum pistons. True--- False---.

13-In order to obtain the greatest wearing surface the piston pin should be clamped in the connecting rod---, the piston---, neither---.

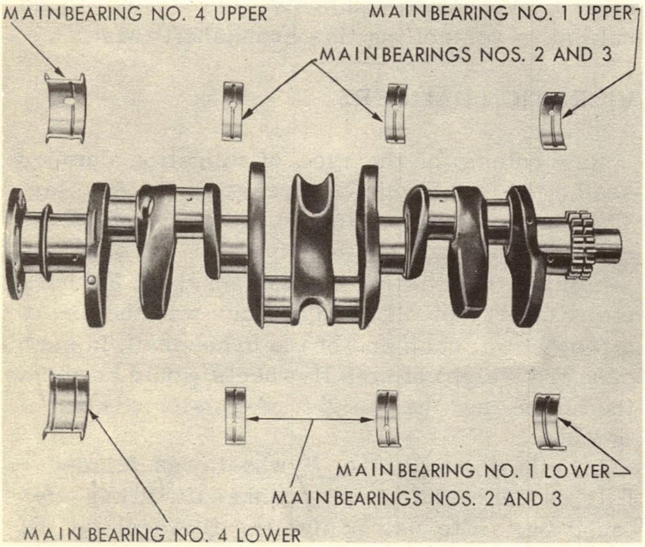
14-A hardened steel pin can be used in an aluminum piston without any bushings. True --- False---.

15-Aluminum and bronze have about the same rate of heat expansion. True--- False---.

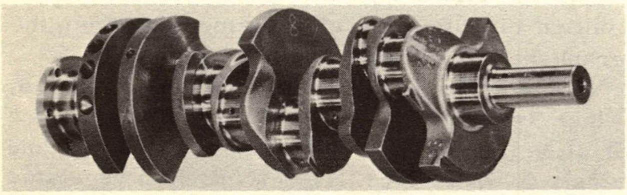
16-Piston pins are not adjustable for wear. True--- False---.

ENGINE CRANKSHAFTS

Automobile engine crankshafts may be forged out of steel, or they may be made out of cast steel by a special process. Examples are shown in Figs. 7-1, and 7-2. They are usually in one piece, although they are sometimes built up of more than one piece. In this case, all pieces must be carefully and rigidly connected. The bearing journals are all finished in precise alignment one with the other, and great care is exercised to see that the journals are absolutely round, and not tapered longitudinally. A high degree of accuracy is necessary in any work that is done with an engine crankshaft or any of the bearings. This will be covered more fully later.

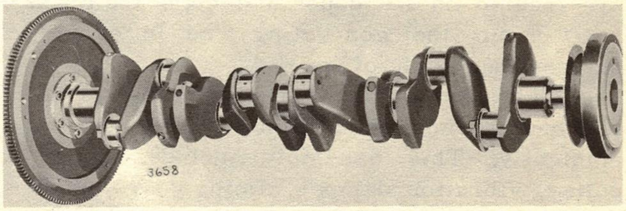


7-1. *Forged steel crankshaft with bearing inserts.*



7-2. *Typical cast steel crankshaft.*

In automobile engines, it is customary to attach a gear or sprocket at the end of the crankshaft opposite the flywheel end, to drive the camshaft either by chain or gear. Also, a torsional vibration dampener is usually attached near the camshaft drive gear or sprocket, to help smooth out the vibration set up in the crankshaft due to the power impulses which have a tendency to twist the crankshaft. See Fig. 7-3.



7-3. *A counter-balanced crankshaft complete with flywheel and vibration damper.*

ENGINE FLYWHEELS

A flywheel is ordinarily mounted near the rear main bearing. This is usually the longest and heaviest of the main bearings, as it must support the weight of the flywheel. The purpose of the flywheel is to assist the engine to idle smoothly by carrying the pistons through those parts of the operating cycle when power is not being produced. The heavier the engine flywheel, the smoother the engine will idle. However, because of its inertia an excessively heavy flywheel will cause the engine to accelerate and decelerate slowly. For these reasons heavy duty or truck engines have large and heavy flywheels and racing car or high speed engines have light flywheels.

The rear surface of the flywheel is usually machined flat and used for one surface of the clutch. In the case of automatic transmissions where no clutch is used, part of the fluid flywheel or torque converter is attached to and becomes a part of the flywheel.

CRANKSHAFT BALANCE

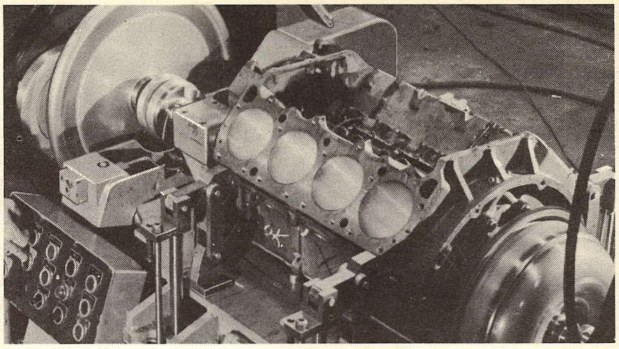
Because of the forces acting on the flywheel and crankshaft and the speed at which it revolves, it is necessary to balance it with great care. The assembly is first balanced statically and then balanced dynamically. To obtain static balance, the weight must be equal in all directions from the center when the crankshaft is at rest. Dynamic balance means balance while the crankshaft is turning. Dynamic balance is attained when the centrifugal forces of rotation are equal in all directions at any point. This balancing operation requires special machinery and involves removal of metal at the heavy points or addition of metal at the light points.

In order to obtain rotating balance, crankshafts are equipped with counterweights which are usually forged or cast integrally with the crankshaft, but in some cases have been bolted rigidly to the crankshaft. These counterweights are located on the opposite side of the crankshaft from the connecting rod in order to balance the weight of the rod.

In addition to balancing the crankshaft proper, the entire rotating assembly is balanced dynamically. This assembly includes the fan pulley, vibration damper, timing gears, crankshaft, flywheel and the clutch or converter parts attached to it. In addition, the connecting rod assemblies including piston pins, pistons, bearings, etc. are all very carefully balanced one with another so that the rotating mass will have as little vibration as possible. See Fig. 7-4.

TORSIONAL VIBRATION

Centrifugal force is one cause of vibration. Inertia forces are another cause. The inertia forces come from the connecting rods and attached parts which have a certain amount of weight and inertia. As their direction of movement is reversed twice each revolution, they must be stopped and started with extreme rapidity. The torsional or twisting vibration is more noticeable in long crankshafts and comes, of course, from the reciprocating movement of the pistons being converted to rotary motion.



7-4. Special equipment is utilized to check the running balance of an engine with the rotating and reciprocating parts in place.

For example, when the No. 1 cylinder fires, it tends to turn the front end of the crankshaft instantly. This force is transmitted through the length of the crankshaft to the flywheel which has considerable inertia. The crankshaft then momentarily "winds up" or twists lengthwise to a small degree, but which is enough to create vibration. Any piece of steel--no matter how heavy--can be twisted slightly by torque applied to it. This twisting of the crankshaft depends upon the forces operating in the engine, and is more severe at some speeds than others. Vibration dampers have been found helpful in controlling this crankshaft twist.

VIBRATION DAMPERS

Regardless of the type of vibration damper used, the principle of operation is similar. They add mass or inertia to the end of the crankshaft opposite the flywheel in order to minimize the twisting of the crankshaft. Perhaps the simplest of all such devices was the use of a flywheel at each end of the crankshaft. In such case the weight of both flywheels would be about the same as the weight of a single normal flywheel.

In other words the flywheel was divided--half on each end of the crankshaft. It has been found better to use a smaller flywheel on the front end and mount it so that it floats. In one type, as shown in Fig. 7-5, rubber is used between the small flywheel and its hub to permit limited circumferential movement between the crankshaft and small flywheel.

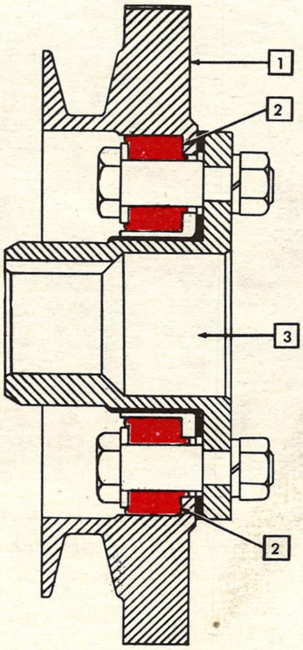
In another type of vibration damper, Fig. 7-6, which resembles a miniature clutch, there is a friction facing mounted between the hub face and small flywheel face. This friction is regulated and adjusted by means of spring tension.

Still another type has the flywheel floating or suspended in fluid such as heavy oil. In any case, the small flywheel because of its mass and inertia, resists sudden twisting of the shaft and thus minimizes torsional vibration.

CRITICAL SPEEDS

No matter how carefully the crankshaft and the parts attached to it are balanced, there will be certain speeds at which some vibration will occur. These are known as critical speeds and will often cause other parts near them to vibrate also. By means of careful design and balancing, these critical periods are caused to occur at speeds outside the ordinary working speeds of the engine.

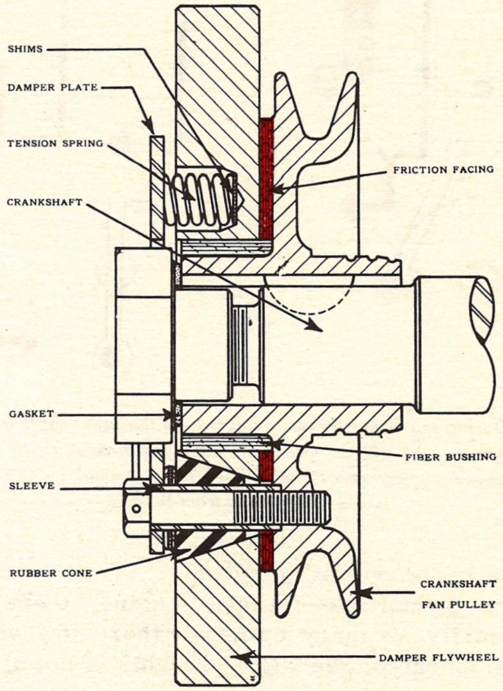
In this connection, it is not too difficult to balance rotating parts, but when reciprocating parts are attached to them the problem becomes much more complicated. We have already given consideration to the fact that each one of the heavy connecting rod and piston assemblies must be started, speeded up, slowed down and stopped twice during each revolution. There are further unbalancing factors that enter into this matter.



7-5. *1. Pulley*
2. Rubber blocks
3. Pulley hub

OTHER CAUSES OF VIBRATION

For example, the piston does not accelerate and decelerate uniformly during each quarter of a revolution. During the first quarter revolution from top dead center (t.d.c.), the connecting rod moves down a distance according to the length of the crank throw and also moves out away from the center of the cylinder. Both the downward and outward motions cause the piston to travel downward. During the second quarter of a revolution, we have a downward motion equal to the crank throw, but the end of the rod is now moving back toward the center line of the cylinder which moves the piston up. The result of this is that the actual movement of the piston is less than during the first quarter turn. This is illustrated in Fig. 7-7.



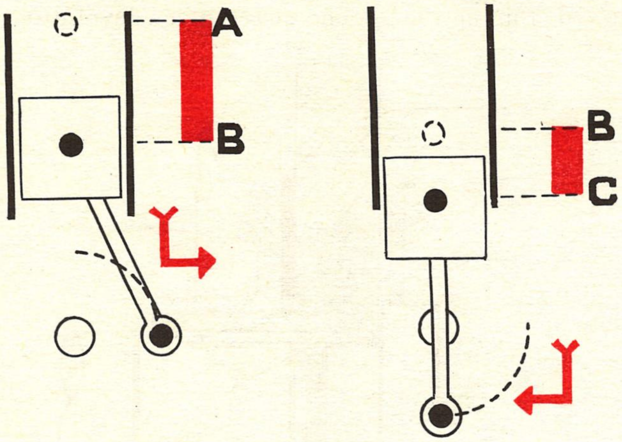
7-6. Another typical vibration damper utilizing friction facings as well as rubber bushings.

It may be seen from the foregoing that all of these forces acting on the crankshaft give it a tremendous job to do. For this reason it is important for the repairman to understand that he cannot add or subtract a fraction of an ounce of weight to any of these parts during a repair operation. Furthermore the crankshaft, bearings, bearing journals, etc. must be in excellent mechanical condition at all times.

ENGINE CAMSHAFTS

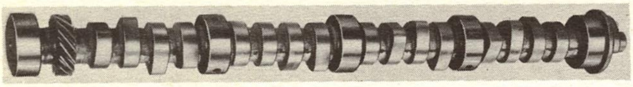
A camshaft in its simplest form is a straight shaft with an eccentric lobe or cam on it. Two such camshafts would be used on a one cylinder, T-head, four cycle, poppet valve engine. One shaft for the inlet valve, another for the exhaust valve. If the engine is of the L-head, I-head or

F-head design, both cams would ordinarily be on the same shaft. These cams would be located at different places around the perimeter of the shaft as the valves need to be opened at different times in the operating cycle.



7-7. During the first quarter revolution of the crankshaft from top dead center, the piston moves the distance from A to B. During the second quarter revolution the distance moved by the piston is less as shown from B to C.

For a multiple-cylinder engine, there are ordinarily as many cams as there are valves to be operated. See Fig. 7-8. This is not always the case however as some V-type engines have had one cam so arranged as to operate one valve in each block. This is usually the case in opposed cylinders or "pancake" engines as shown in Fig. 7-9. In four-cycle engines, each valve is opened once every other revolution of the engine crankshaft so the camshaft is geared to run at half the crankshaft speed.



7-8. Typical eight cylinder (V-8) camshaft.

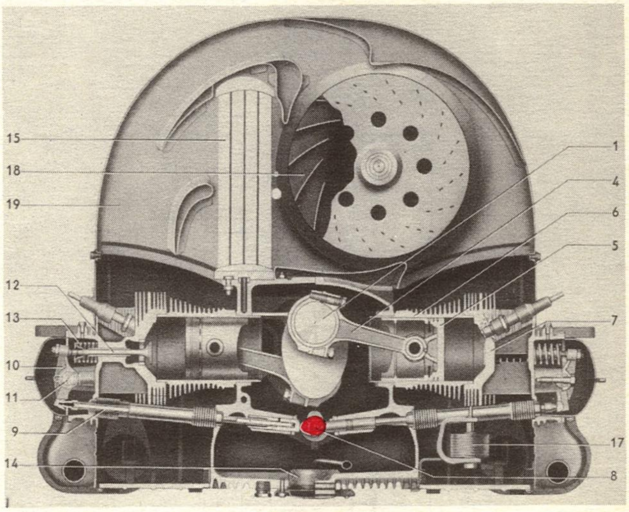
As the camshaft is not subjected to such severe reciprocating forces and runs at slower speed than the crankshaft, it is much smaller and has smaller bearings. The camshaft is made of steel and the cams are hardened to avoid rapid wear on the cam surface.

These cams appear to have a simple shape, but actually the exact shape of the cam is a meticulous job of design. See Fig. 7-10. The design is worked out after a painstaking and detailed program of mathematical calculation, and checked by lengthy experimentation. If the shape of the cams is altered by wear, the efficiency of the engine deteriorates with great rapidity. There is much more to the matter than just opening and closing a valve.

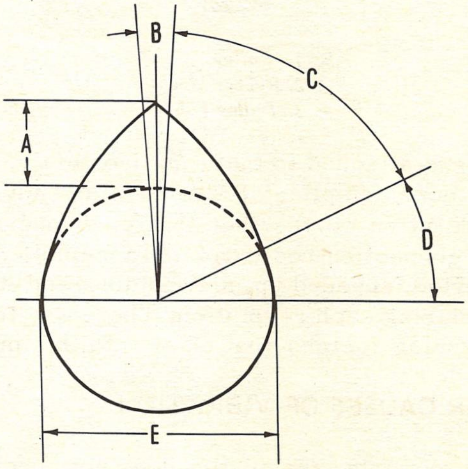
CAM FUNCTIONS

The cam is designed to lift the valve at precisely the correct instant of piston travel and hold it open long enough to obtain the most efficient filling and emptying of the cylinder. It exerts considerable control over the volumetric efficiency of the engine. This will be discussed fully later in this text.

In a passenger car engine, ramps on the cams are designed to open the valves smoothly and gradually. This avoids shock to the valves, valve springs, etc., and makes for quietness of



7-9. The camshaft (8) is below the crankshaft (1) in this Volkswagen pancake engine and each cam operates two valves--one on each side.



7-10. A is the height of lift, B the toe section, C the flank area, D the ramp, and E the heel diameter of the cam.

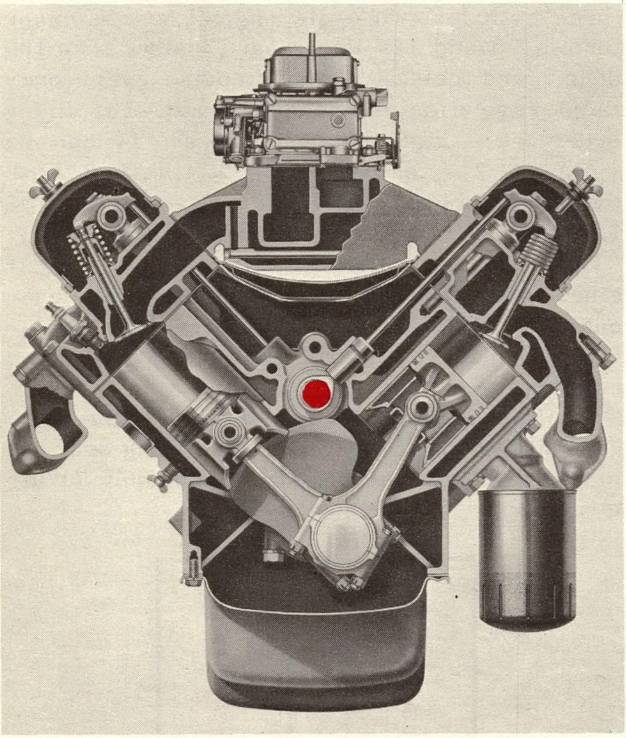
operation. The final design is usually a compromise between efficiency and quietness of operation.

On racing engines where noise is not important and utmost efficiency is desired, the cams are often shaped with more abrupt ramps, higher lift, flatter flank and wider toe. The cam is intended to "bat" the valve open quickly, open it wider, hold it open longer and close it rapidly. Such engines are noisy, idle roughly and wear more quickly.

If the camshaft is chain driven, it rotates in the same direction as the crankshaft which is clockwise from the front of the engine. If the camshaft is driven by a gear meshed with a mating gear on the crankshaft, the camshaft rotation is counterclockwise, or opposite from the crankshaft.

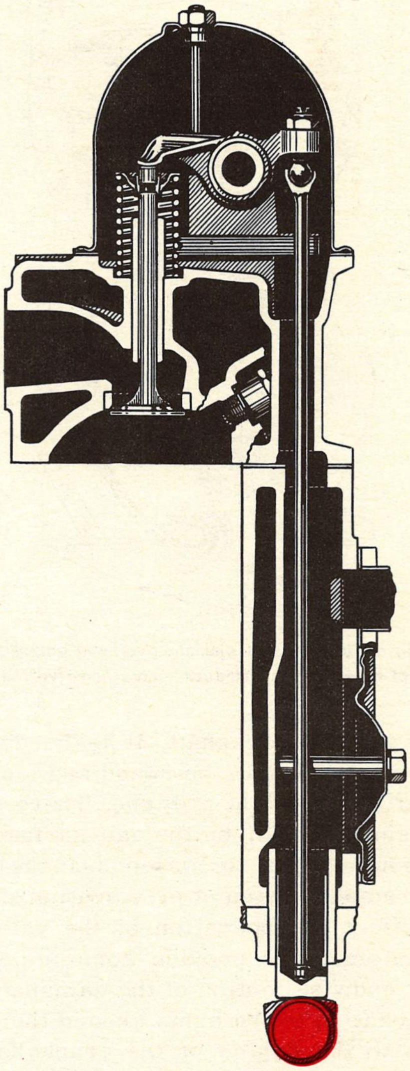
CAMSHAFT LOCATION

On an L, F or I-head, in-line engine, the camshaft is usually located to one side and above the crankshaft. On V-type engines, the camshaft is usually located directly above the crankshaft as shown in Fig. 7-11.

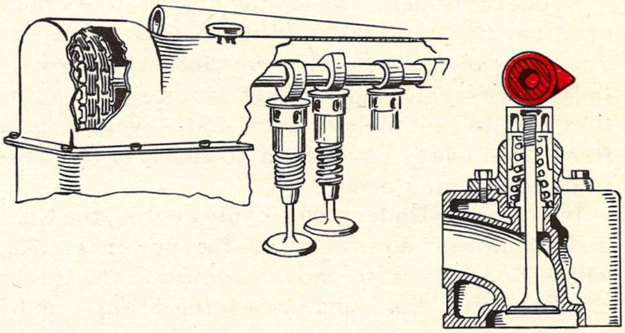


7-11. Usual location of V-type engine camshaft.

On the overhead camshaft engine--not to be confused with overhead valve engines--the camshaft is located above the cylinder head. See Figs. 7-12 and 7-13. The overhead camshaft may be driven by means of a shaft and bevel gears, but is more often chain driven. In either case, the cams bear directly on the end of the valve stems. This construction avoids the use of valve push rods, rocker arms, etc. It does permit excellent valve action at high speed, as the

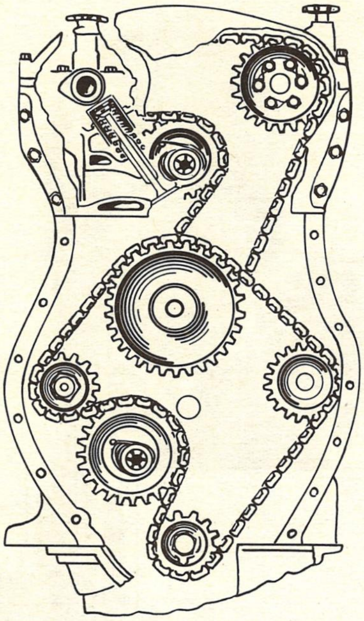


7-12. Typical valve operating mechanism or "train" for an overhead valve engine.



7-13. Typical valve layout for overhead camshaft type of engine.

inertia of reciprocating parts in the valve train is eliminated. However such construction is usually expensive and there are difficulties of timing chain lag and noise caused by multiple gears or long chain drives. See Fig. 7-14.



7-14. Long chains used to operate overhead camshafts are subject to wear and introduce errors in valve timing.

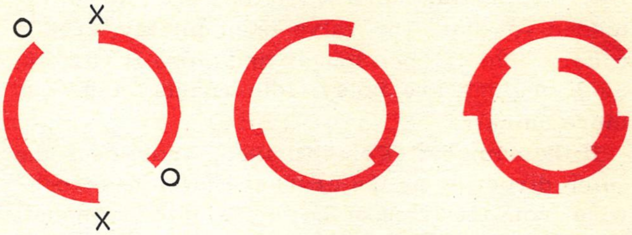
As with the crankshaft, it is necessary that the camshaft journals be round and true, and the camshaft be straight and true. There should be no measurable wear on the cam surfaces. There must be no appreciable looseness in the bearings, as any radial movement or vibration of the cams would affect the operation of the valves. It is also customary to provide some adjustment to prevent endwise motion of the camshaft.

The location of the cams around the camshaft along with the design of the crankshaft determines the firing order of the engine.

FIRING ORDER

A one-cylinder, two-cycle engine fires once each revolution. A one-cylinder, four-cycle engine fires once every other revolution. A two-cylinder, two-cycle engine fires twice each revolution, while a two-cylinder, four-cycle engine fires once every revolution so there is no question about firing order.

In a four-cylinder, four-cycle engine, the No. 1 piston moves downward on the power stroke, while No. 4 is also moving down on the intake stroke. While No. 1 and 4 are going down, 2 and 3 are, of course going up. One is on the exhaust stroke; the other on the compression stroke. There are therefore two possible firing orders, 1, 2, 4, 3 or 1, 3, 4, 2. In either case, one power impulse is obtained every one-half revolution of the crankshaft, giving two power impulses per revolution. See Fig. 7-15.

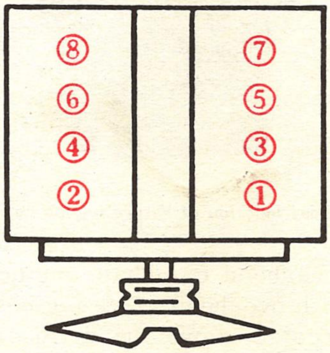


7-15. With the four cylinder engine, a power impulse is obtained every half revolution as shown by the diagram at the left. The space between O and X indicates the time the exhaust valve is open during the power stroke and no power is obtained. With the six cylinder four cycle engine, (or the three cylinder, two cycle engine) there is a power impulse being exerted at all times with three impulses per revolution. There is also a slight overlap period when two cylinders are exerting power. With the eight cylinder in-line engine as shown at the right, there is considerable overlap of the power impulses as they occur each quarter revolution.

The six-cylinder four-cycle engine (and a three-cylinder two-cycle engine) has the crank throws spaced 120 deg. apart, rather than 180 degs., and gets a power impulse every one-third revolution of the crankshaft. The firing order of a right-hand crankshaft can be 1, 5, 3, 6, 2, 4, or it can be 1, 2, 4, 6, 5, 3. With the left-hand crankshaft, the firing order can be 1, 4, 2, 6, 3, 5, or it can be 1, 3, 5, 6, 4, 2.

With an eight cylinder in-line four-cycle engine, there will be a power impulse every one-quarter revolution (90 deg.) of crankshaft rotation. There are several possible firing order combinations.

While different firing orders are used, the general idea of an in-line engine firing order is to fire cylinders as nearly as possible at alternate ends of the crankshaft.



7-16. One popular V-8 firing order is 1, 4, 5, 2, 7, 6, 3, 8.

On a V-type engine the objective is to alternate between the ends of the crankshaft and the cylinder blocks on each side, to distribute the forces around over the engine and avoid concentrating subsequent explosions near one point of the crankshaft. This reduces vibration, and makes for a smoother running engine. A popular firing order is shown in Fig. 7-16.

QUIZ - ENGINE CRANKSHAFTS

1-What is the purpose of a flywheel?

2-What is the difference between static and dynamic balance?

3-Torsional vibration is more noticeable in an in-line eight crankshaft than in a V-eight crankshaft. True--- False---

4-Describe the most simple type of vibration damper.

5-When the crankshaft rotational speed is constant, is the distance travelled by the piston during each quarter revolution the same? Yes--- No---.

6-How many possible firing orders are there for a four-cylinder, four-cycle engine? One --- Two--- Four---.

7-A six cylinder four-cycle in-line engine camshaft has how many lobes on it? Six--- Twelve--- Eighteen---.

8-Is more than one valve ever operated by one cam? Yes--- No---.

9-A worn cam flank will cause: Noise---Loss of power--- Oil pumping---.

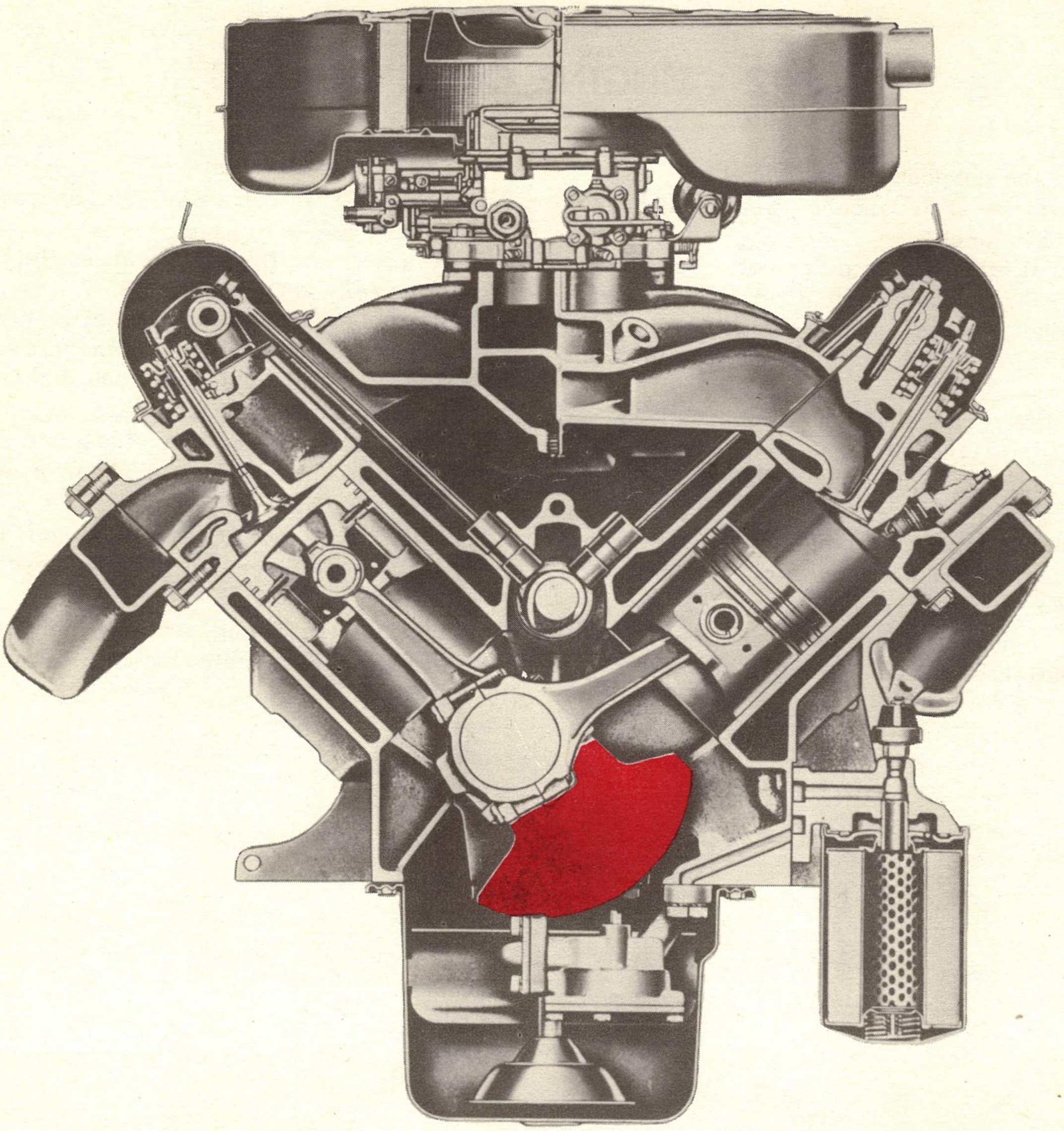
10-What is the difference between an I-head engine and an overhead camshaft engine?

11-Name one advantage and one disadvantage of overhead camshaft engines.

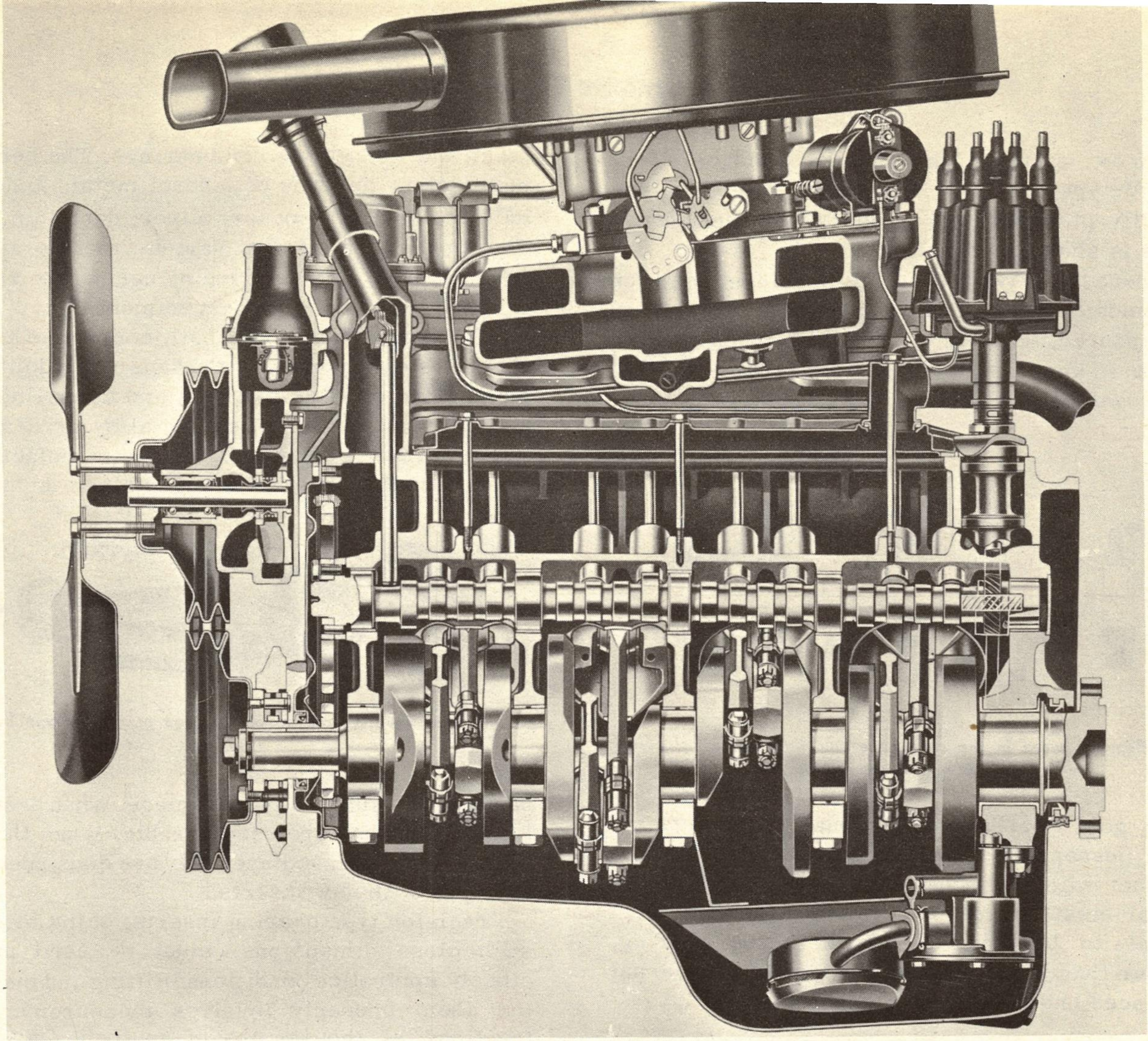
12-How many power impulses per revolution occur in an eight-cylinder four-cycle engine? Four--- Eight--- Sixteen---.

13-How many power impulses per revolution occur in a three-cylinder two-cycle engine? Three--- Six--- Twelve---.

14-Why is the firing order of V-type engines arranged differently than on in-line engines?



The crankshaft counter weight in this Ford engine, is forged as an integral part of the crankshaft.



8-1. This V-8 has a main bearing between each pair of cylinders, and the connecting rods are placed side by side in pairs.

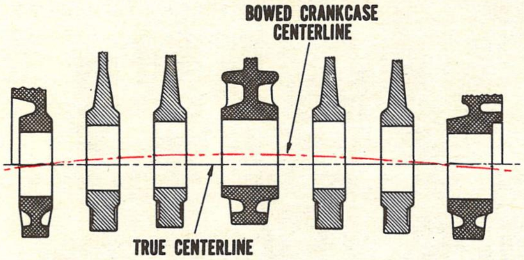
ENGINE BEARINGS, VALVES

A one or two-cylinder engine will usually have two main bearings, a front main bearing and a rear main bearing. The rear main bearing is always adjacent to the flywheel. A four-cylinder engine normally has three mains, one at the front, one between cylinders No. 2 and No. 3, and one at the rear. However, some four-cylinder engines have five main bearings, one between each cylinder. An eight cylinder V-type engine may have three but usually has five main bearings. See Fig. 8-1.

In a previous chapter reference was made to cylinder block distortion. This can be serious if the crankcase distorts to throw the engine main bearings out of alignment with each other. An example of this is shown in Fig. 8-2.

On engines having less than eight cylinders and on in-line eights it is customary to provide a throw on the crankshaft for each cylinder. On V-type engines, however, the rods are usually placed side by side, two on each throw. This is shown in Fig. 8-1.

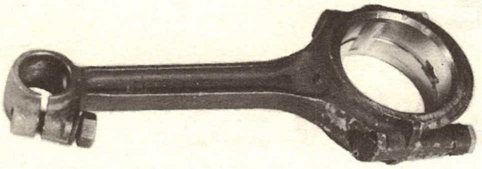
There are two types of bearings used on automobile engine crankshafts. One is known as the poured, cast-in or integral type, and the other is known as the precision or slip-in type. The bearing surface is in all cases a soft metal with good heat conducting qualities and which will possess a low co-efficient of friction in contact with the steel crankshaft journal. The metal must be soft to allow any abrasive material to become imbedded in the bearing, rather than remain between bearing and journal surfaces and damage the journal.



8-2. Bearing bores in the crankcase can warp out of alignment and cause serious trouble.

INTEGRAL BEARINGS

Integral or poured bearings are made by pouring molten babbitt or bearing metal into the bearing seats. The seats are first tinned and the bearing metal adheres permanently until melted out. See Fig. 8-3.

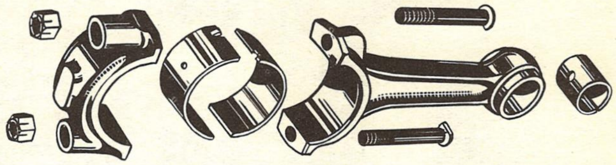


8-3. This connecting rod has an integral type of bearing.

PRECISION BEARINGS

The precision or slip-in type of bearing as shown in Fig. 8-4, has become increasingly popular since engine speeds and loads have been increased so much that a material stronger than babbitt became necessary. It is now used in the majority of automobile engines for both main and connecting rod bearings. The bearing material is an alloy of several metals and may include lead, tin, copper, silver, cadmium, etc. The proportion of the various metals varies considerably, and the development is the result of much experience and experiment.

The bearing insert or shell, consists of a hard shell of steel or bronze, perhaps with additional metal linings or laminations, and a thin lining of anti-friction metal or bearing alloy to form the inner surface. These inserts are manufactured to extremely close dimensions and must be handled carefully to avoid damage. When properly installed they are very durable. When they do wear from continued use, they are discarded and replaced with new inserts.

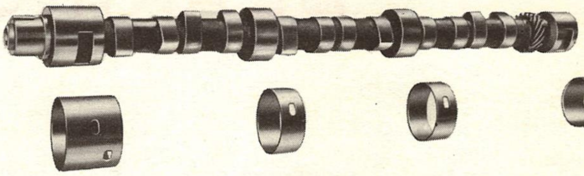


8-4. This connecting rod assembly uses precision type bearing inserts.

Precision type bearing inserts, being made to such close dimensions, must be used under closely controlled conditions. Fitting and installing them properly involves measurement in fractions of thousandths of an inch. Careless workmanship in installation cannot be tolerated, as they are not adjustable. We will consider fitting them later in this text.

CAMSHAFT BEARINGS

Camshaft bearings are usually made of bronze, and are bushings rather than in the form of split bearings. See Fig. 8-5. Sometimes the camshaft bears directly in a hole bored in the crankcase without any bushing. Camshaft bushings are not adjustable for wear and are replaced when worn. The degree of wear dictating replacement is more a matter of oil clearance than any tendency toward noise. This will be

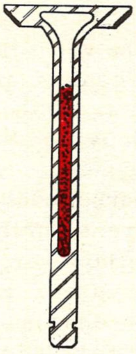


8-5. The holes in these camshaft bushings are for lubrication purposes.

considered fully in the chapter devoted to lubrication.

ENGINE VALVES

Internal combustion engine valves have a tremendous task to perform and under the very best conditions they are not all that could be desired. The conditions under which the valves operate would seem to impose an impossible task upon them, but they have been developed to a point where they are fairly efficient. A great amount of ingenuity has been expended upon sleeve valves, rotary valves, slide valves and poppet valves. The poppet valve despite all its shortcomings is used almost universally.



8-6. This hollow valve stem is partially filled with sodium which melts when the valve gets hot and bounces back and forth between head and stem to assist the heat to flow from head to stem.

Poppet valves are noisy and it is difficult to cool them, but they are simple and do provide an effective seal under operating conditions.

These operating conditions are brutal. The valves are in the combustion chamber and are exposed to the burning gas, but are not surrounded with cooling water as is the combustion chamber. Neither are they cooled by the oil as is the piston. The explosion temperature within an engine combustion chamber may momentarily approach 5,000 degs. F. and the exhaust valve must then open and permit these hot gases to go between the valve head and the cylinder block at high velocity.

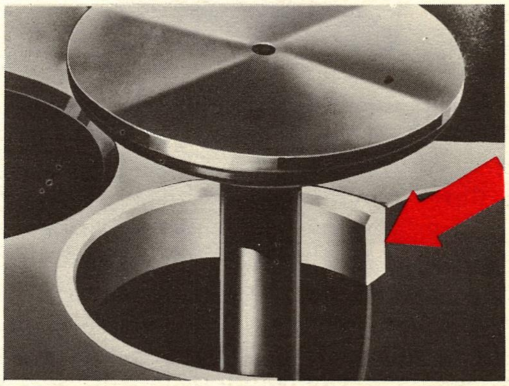
It may be readily seen that the exhaust valve head may attain a temperature of 1,000 degs. or more under these conditions. The valve cannot readily be cooled directly by the cooling water in the engine and the only cooling comes from contact with the valve guides and with the cylinder block during the short space of time it is in contact with the valve seat. How short this space of time is may be realized if thought is given to the speed at which the engine operates.

If the engine is operating at 3,000 r.p.m. that means that any one cylinder will fire 1,500 times in that minute and that every time the cylinder fires, the exhaust must open to let the burned gas out. Obviously, if the valve is lifted off its seat 1,500 times each minute, it will not remain in contact with the valve seat long enough at any one time for much of the heat to flow out of it.

VALVE TEMPERATURES

It is not difficult to understand why exhaust valves are prone to cause trouble. In normal operation the valve head around the seating surface will operate at a temperature of 1,000 to 1,200 degs. F. The central portion of the valve head will run somewhat hotter, 1,200 to 1,400 degs. and the stem adjacent the head perhaps 800 to 1,000 degs. Running thus at a red heat under normal conditions, it may be seen that the steel valve may melt under abnormal conditions such as a leaking valve or a cooling disorder.

The inlet valve has a somewhat easier task as it is not exposed to the burning gas while it is off its seat. The inlet valve is also cooled by the incoming gas mixture which is at or below atmospheric temperature.



8-7. These alloy inserts are often pressed or shrunk in place.

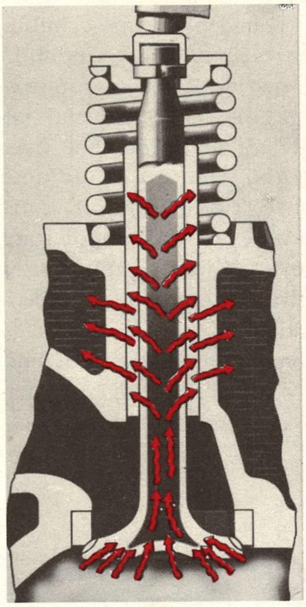
HEAT RESISTANT ALLOYS

Exhaust valves are usually made of heat resistant alloy steel. Quite often they are partially filled with mineral salts to help them get rid of the heat. See Fig. 8-6. The valve seat is often also made of heat resistant alloy in the form of an insert which is set into the cylinder head or block under the exhaust valve. See Fig. 8-7. These inserts are used in cast iron blocks or heads as well as aluminum heads or blocks.

The particular construction shown in Fig. 8-8 has a special heat resistant alloy on the valve face and also bears on a heat resistant valve seat insert. Such construction is used in heavy-duty engines.

VALVE COOLING

The heat flows from the valve head to the cooling water as shown in Fig. 8-8. Some heat also flows from the valve head to the valve seat during the brief time the valve is seated.



8-8. *The major part of the heat from the valve head flows to the valve stem and on to the cooling water as shown here.*

Heat will flow through a solid piece of metal more efficiently than from one piece of metal to another, regardless of how tightly the two pieces are held together. An inserted alloy valve seat will run hotter than if the seat were a part of the head or block. However, the special alloy can also withstand much higher temperature without damage. Such inserts also can be replaced with new ones if they do become damaged.

It will also be noted that the heat flows from the valve stem to the valve guide and from the guide to the head or block. Here again the heat transfer would be facilitated if the valve stem was in direct and intimate contact with the head or block. Some authorities claim that thus dispensing with the guide will lower the operating temperature of the exhaust valve as much as 100 degs. F. Of course separate valve guides can be readily replaced when worn. When no guides are used, it is necessary to ream the head or block guide holes and install oversize valves when wear occurs.

VALVE SEAT CONTACT AREA

From the foregoing, it should be realized that anything that reduces the area of contact between the valve and the cylinder head or block will hamper the escape of heat from the valve. Thus if the valve seat is too narrow or the valve guide worn excessively, the area of contact will be reduced and the valve will overheat.

The area of contact could be increased by widening the valve seat, but it has been found that a wider seat also encourages flakes of carbon to adhere, hold the valve off the seat and cause burning of the valve face. Another method of increasing the contact area would be to increase the diameter of the valve head or the valve stem or both by installing oversize valves, oversize or longer guides, etc.

There are of course mechanical limitations to the amount of increase in these dimensions. Of more importance however, would be the increase of weight in the valve. The valve is required to move endwise with such rapidity that it must be kept as light in weight as possible. Any excess weight would add to the inertia and slow down the valve action. So here again a compromise must be made and a reasonable limitation in size imposed.

VALVE HEAT DISSIPATION

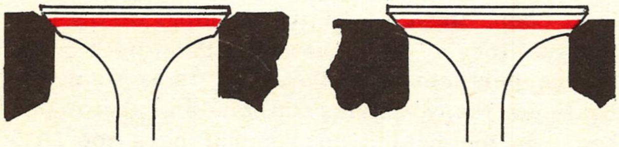
This matter of valve heat dissipation must be thoroughly understood if automobile engines are to be serviced properly. There are several things to be considered in this connection. Some of them are similar to problems previously discussed in connection with pistons and rings.

8-9. *If the valve has a thin edge as shown at the left or if the valve head is warped as shown at the right, the thin edges thus created will become excessively hot.*

For example, the heat of operation causes distortion of cylinder heads, blocks, etc. The same conditions cause distortion of valve and valve seat. Any hot spots in the cylinder head or block near the valves or any unequal tightening of the cylinder head bolts will aggravate distortion and cause valve difficulties. The valve and seat may be round and true when the engine is cold, but may not be round and true when the engine gets to operating temperature.

The valve head is liable to warp due to the difference in temperature at different points. This warpage will be aggravated if the rim of the valve head is thin or uneven. See Fig. 8-9. Furthermore, the temperature may vary around the rim of the valve head in some cases due to the difference in volume and velocity of the gas going between the valve and seat as determined by combustion chamber design and valve port shape.

In addition to changes in valve and valve seat shape, the diameter of both may change. The valve head runs hotter than the valve seat because the seat is nearer the cooling water. Therefore the valve head may expand more than the seat and as a result the valve may rise on the seat as shown in Fig. 8-10. This action results in a change in the valve seat area location.



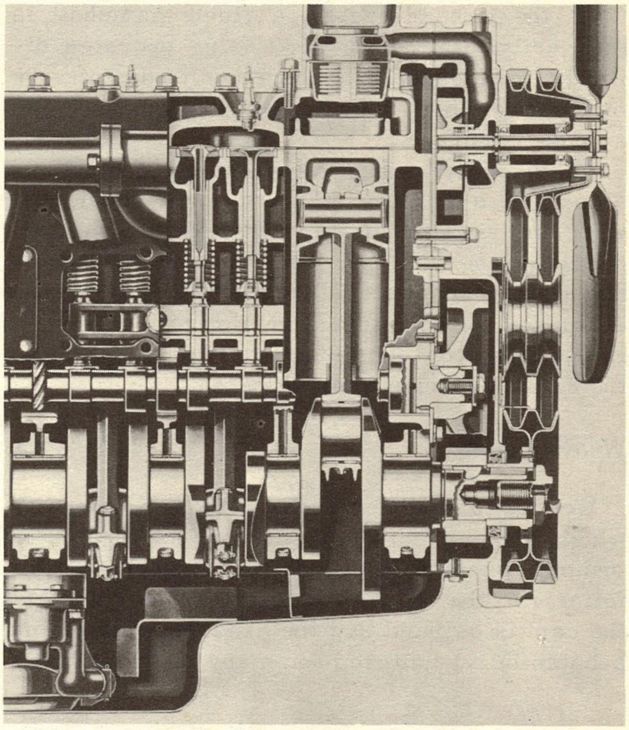
8-10. An exhaust valve may be properly seated as at the left when cold, but may expand rapidly and climb off the seat as shown at the right.

It will be apparent that the dimension between the valve seat and the valve lifter will be lengthened by such expansion. The length of the valve itself between the seat surface and the end of the stem, will be altered by lengthwise expansion of the valve and valve stem. These changes in dimension may in some cases compensate for each other to a certain extent--or they may not. Much depends upon the design of the engine. The serviceman cannot change the engine design, but he must understand all of these things in order to adjust the mechanism to allow for such variations, and insure satisfactory operation of the engine.

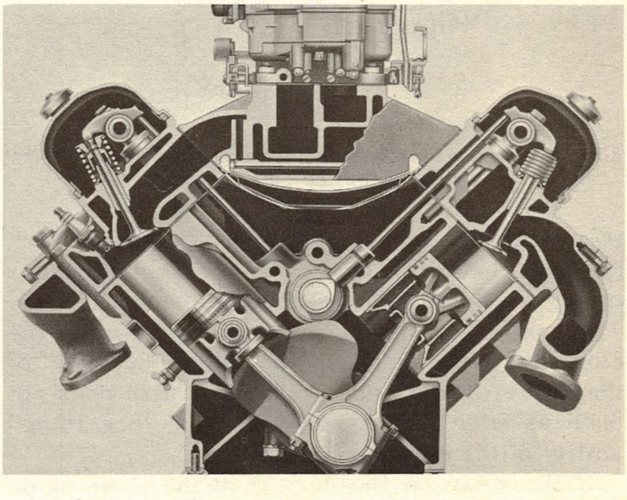
VALVE OPERATING MECHANISM

The camshaft is rotated by the engine crankshaft, by means of gears or chains, and thus is kept in definite relation or "timing" with the crankshaft. In four-cycle engines, the camshaft sprocket or gear is twice the diameter of the crankshaft gear or sprocket, and therefore operates at half the speed of the crankshaft.

In the L-head engine, where both valves are on the same side of the cylinder, it is customary to place the camshaft directly under the valves and operate the valves with short push rods. See Fig. 8-11. In the overhead valve engine, a single camshaft is usual with a cam for each valve, but in this case a long push rod is used to operate a rocker arm which operates the valve. See Fig. 8-12. As the rocker arm, valve



8-11. L head valves are lifted by means of short push rods which are adjustable for length.



8-12. Overhead valves require push rods and rocker arms which are mounted on a rocker shaft.

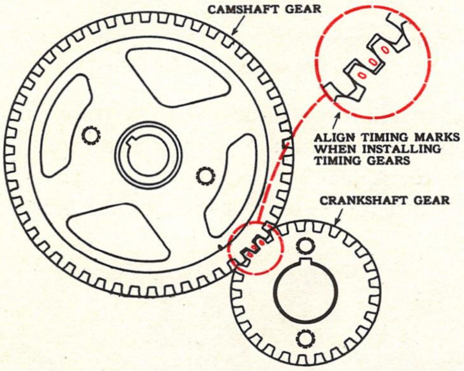
and push rod all reciprocate, this represents considerable weight per valve. This has been overcome in the case of overhead camshafts which are mounted directly on top the overhead valves above the engine. This is a satisfactory method, but brings in complications of cost and accurate valve timing.

On the F-head engine, a single camshaft is ordinarily used, one valve being operated directly by means of a short push rod, and the other valve being operated by a long push rod and a rocker arm.

As the valves must be precisely opened and closed with relation to the piston travel, any wear in the camshaft driving chain or gear will result in the valve not being opened and closed at the exact instant desired and a loss in engine efficiency will be incurred. For this reason, it is usual to avoid long chains or multiple gears in the camshaft drive arrangement.

WORN CAMS

We have already considered the accuracy with which the cam shape or contour is formed in order to provide the proper operating characteristics for the valves. Ordinarily the surface of the cam is so hard that the exact shape remains substantially unaltered for many thousand miles of operation. There is of course some friction between the cam and the valve lifter that rides on it, and some wear is bound to occur in time. This wear is usually on the highest part of the cam, and will decrease the height or "lift" of the valve. The result is that the valve does not open as wide as it should, and the "breathing" ability of the engine suffers.



8-13. Timing gears are usually marked as shown to insure that the valves will be correctly timed.

If the wear on the cam is at the sides or on the ramp, the valve action will become noisy, and also the valve will open late or close early, or both. Excessive wear in the valve lifters will have the same results; noise and faulty valve timing.

Usually the wear on cams is so slow and the loss of engine performance so gradual that it goes unnoticed unless the valve lift is checked against factory specifications. In rare cases a defective camshaft has been found, and the loss of engine performance so rapid as to be noticed. In some cases the entire camshaft was not properly hardened, and in other cases it has been one or more individual cams that were soft enough to wear quickly.

VALVE TIMING

Anything that occurs to change the time that the valve opens, the duration of the time it is held open, the size of the opening, or the time that it closes, will have a decided effect on the engine performance. This fact is seldom fully realized. Many engines run constantly below par, because mechanics in general have too little knowledge of the necessity of proper valve clearance adjustment.

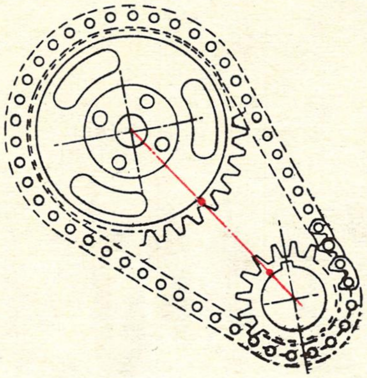
A full realization of the need for accurate adjustment can come only from a study of valve action and requirements. This study starts with the relation between the crankshaft and camshaft. Due to the difference in the diameter of the circles described by the crank throw, and the cam nose and the difference in the comparative speed of rotation, the crank throw may travel many times as fast as the cam nose. While the cam nose is moving 1/4 in., the crank throw may move 1-1/2 in. If the cam is a few thousandths late in opening the valve, the crank throw and the piston attached to it will move a considerable distance farther than it should before the valve opens.

In this manner the motion of the piston is partially lost, and the power output suffers. Obviously, therefore, a worn timing chain or gears should be replaced as soon as the wear exceeds the specifications rather than run them until they become noisy or break, which is all too often the case.

In a few cases, adjustment is provided for timing chains such as an eccentric mounting for an accessory shaft, automatic slack adjusters, etc. In most cases it is necessary to install a new chain.

In a gear-driven camshaft, the crankshaft gear is usually made of steel but the camshaft gear is often made of non-metallic composition. This non-metallic substance is quite durable and also makes for quieter operation. These gears are not adjustable and must be replaced when worn.

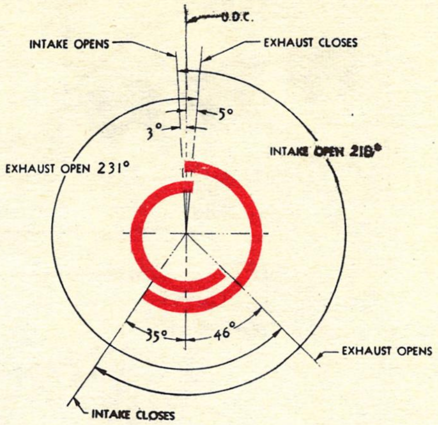
The car manufacturers set up specifications as to the amount of wear permissible in the chain or between the gear teeth. They also mark the gears or chains to facilitate correct timing. See Figs. 8-13 and 8-14. In addition, they also furnish timing charts by means of which valve timing can be readily checked.



8-14. Timing chain sprockets are usually marked so that when a line drawn through the center of both shafts bisects the timing marks, the timing is correct. Flywheels are also usually marked to facilitate checking the valve timing.

The extreme accuracy with which it is desired to open and close the valves may be understood when thought is given to the speed at which the valve parts operate. This timing becomes more important as engine speeds are increased. This is the reason for what is known as valve "overlap." Valve overlap means that the intake and exhaust valves may both be open at the same time in any one cylinder. This, however, is to compensate for the time required by the air or gas to flow through the manifolds.

Theoretically, of course, the inlet valve should open at the time the piston starts down in the cylinder and should close at the instant the piston starts up in the cylinder on the compression stroke. Both valves should remain closed during compression and expansion, and the exhaust valve would then open at the end of the power stroke and close at the end of the exhaust stroke. Such would be a satisfactory cycle for a slow speed engine. A valve timing diagram for a typical high speed engine is shown in Fig. 8-15. It will be noted that the inlet valve opens 3 deg. before T.D.C. while the exhaust valve does not close until 5 deg. after T.D.C. Therefore both inlet and exhaust valves are open during 8 deg. of crankshaft rotation.



8-15. This diagram illustrates the overlap or time during which both valves are open in the same cylinder. This is necessary in a high speed engine to compensate for the inertia of the gas moving into and out of the cylinders.

QUIZ - BEARINGS, VALVES

1-Is an integral bearing and a precision bearing the same thing? Yes--- No---

2-Why is bearing metal comparatively soft?

3-Bushings are always used on all camshaft journals. True--- False---.

4-Slip-in bearings are not adjustable for wear. True--- False---.

5-Name four metals used in bearing metal alloys.

6-Valve seats can be too wide. True--- False ---.

7-Valves are sometimes hollow to make them lighter in weight. True--- False---.

8-Excess heat gets out of the valve by flowing to the valve seat---, the valve guide---, both ---.

9-Why are valves not made larger?

10-An exhaust valve may reach a temperature of 500 deg. F.---, 1,000 deg. F.---, 3,000 deg. F.---.

11-Valve length is not constant. True--- False ---.

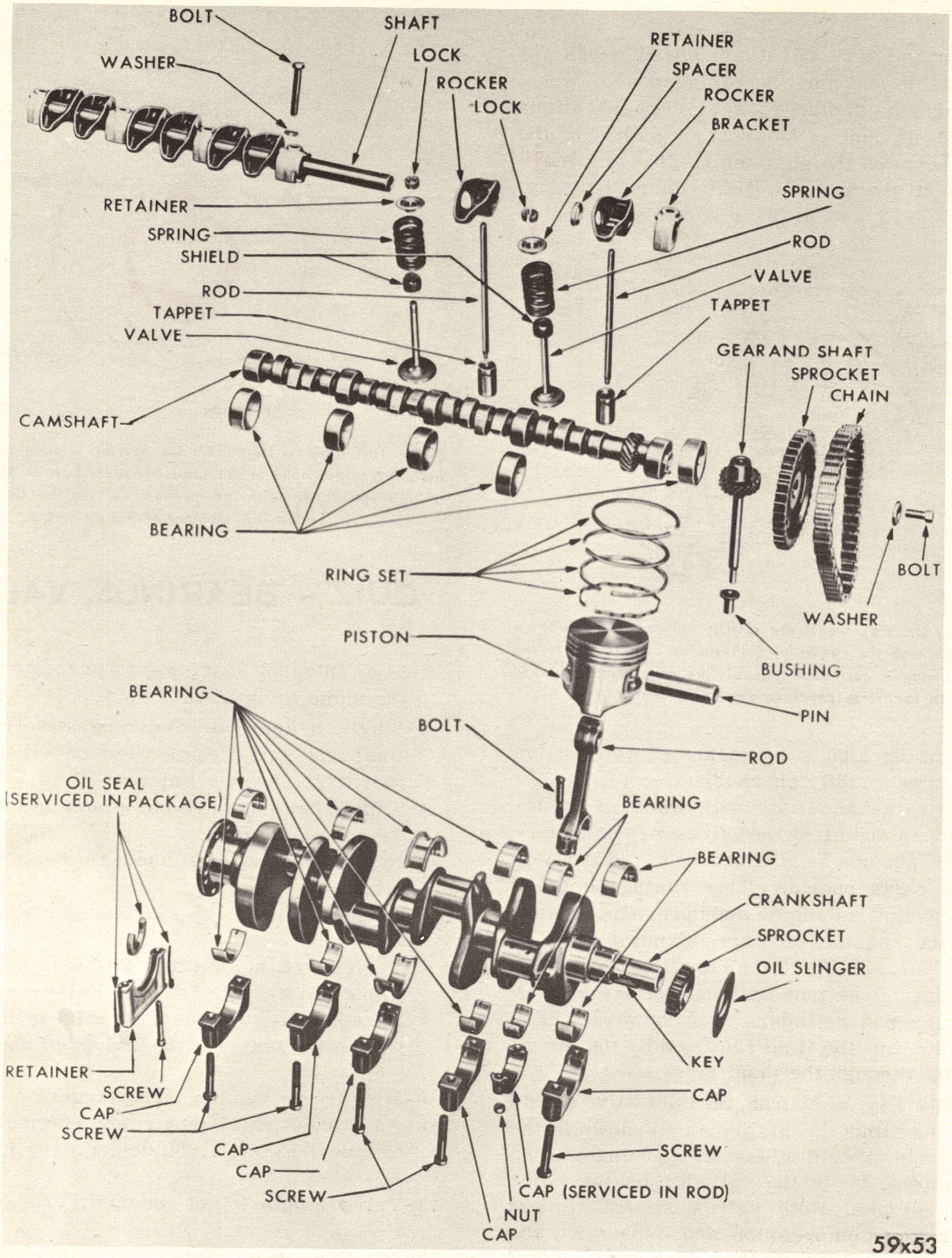
12-At what speed does the camshaft operate? Half crankshaft speed---, the same speed ---, twice the crankshaft speed---.

13-What is the objection to a long chain in a camshaft drive?

14-The cam nose travels faster than the crank throw. True---False---.

15-Are timing chains adjustable for wear? Yes---, No---, Sometimes---.

16-What is valve overlap?


BOLT
WASHER
SHAFT
LOCK
ROCKER
LOCK
RETAINER
SPACER
ROCKER
BRACKET
SPRING
RETAINER
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ROD
TAPPET
VALVE
ROD
VALVE
TAPPET
GEAR AND SHAFT
SPROCKET
CHAIN
CAMSHAFT
BEARING
RING SET
BOLT
WASHER
PISTON
BUSHING
PIN
BEARING
BOLT
ROD
OIL SEAL (SERVICED IN PACKAGE)
BEARING
BEARING
CRANKSHAFT
SPROCKET
OIL SLINGER
KEY
RETAINER
SCREW
CAP
SCREW
CAP
CAP
SCREW
CAP
SCREW
CAP (SERVICED IN ROD)
NUT
CAP
59x53

Relation of reciprocating and rotating parts as found in current Plymouth engine design.

ENGINE PERFORMANCE

RATED HORSEPOWER

Horsepower ratings are sometimes confusing as several different terms are used. One term is the rated horsepower which is used for licensing purposes. The rated horsepower designation has been with us since the early days of inefficient engines. At that time a measurement of engine size was desirable and a formula was developed which was felt to be usable for all engines. This consisted of taking the bore in inches multiplied by itself, multiplied again by the number of cylinders, and divided by 2.5. For example: a four cylinder engine having a cylinder bore of 4 in. and a piston stroke of 4 in. would be rated at 25.6 hp.

$4 \times 4 = 16 \times 4 = 64 \div 2.5 = 25.6$

While it was a crude measure and served its purpose at the time, it is now misleading as we get several times as much power out of an engine of given size as we did at that time.

DEVELOPED OR BRAKE HORSEPOWER

The cubic inch piston displacement is a much more reliable figure for indicating the potential power output of the engine. Piston displacement is the number of cubic inches of space displaced by the pistons as they move in the cylinders away from the crankshaft. The cubic inch displacement of an engine can be obtained mathematically from the engine dimensions.

The area of the piston head is obtained by squaring the bore (the inside diameter of the cylinder, times the inside diameter of the cylinder) and multiplying this figure by .7854. This gives the area of one piston. This figure multiplied by the stroke (the length of the distance the piston travels in the cylinder) in inches gives the displacement of one piston. The displacement of one piston in cubic inches, multiplied by the number of cylinders, will provide the piston displacement of the engine. For example: again using the four cylinder 4 x 4 engine, the displacement would be 50.2656 cu. in.

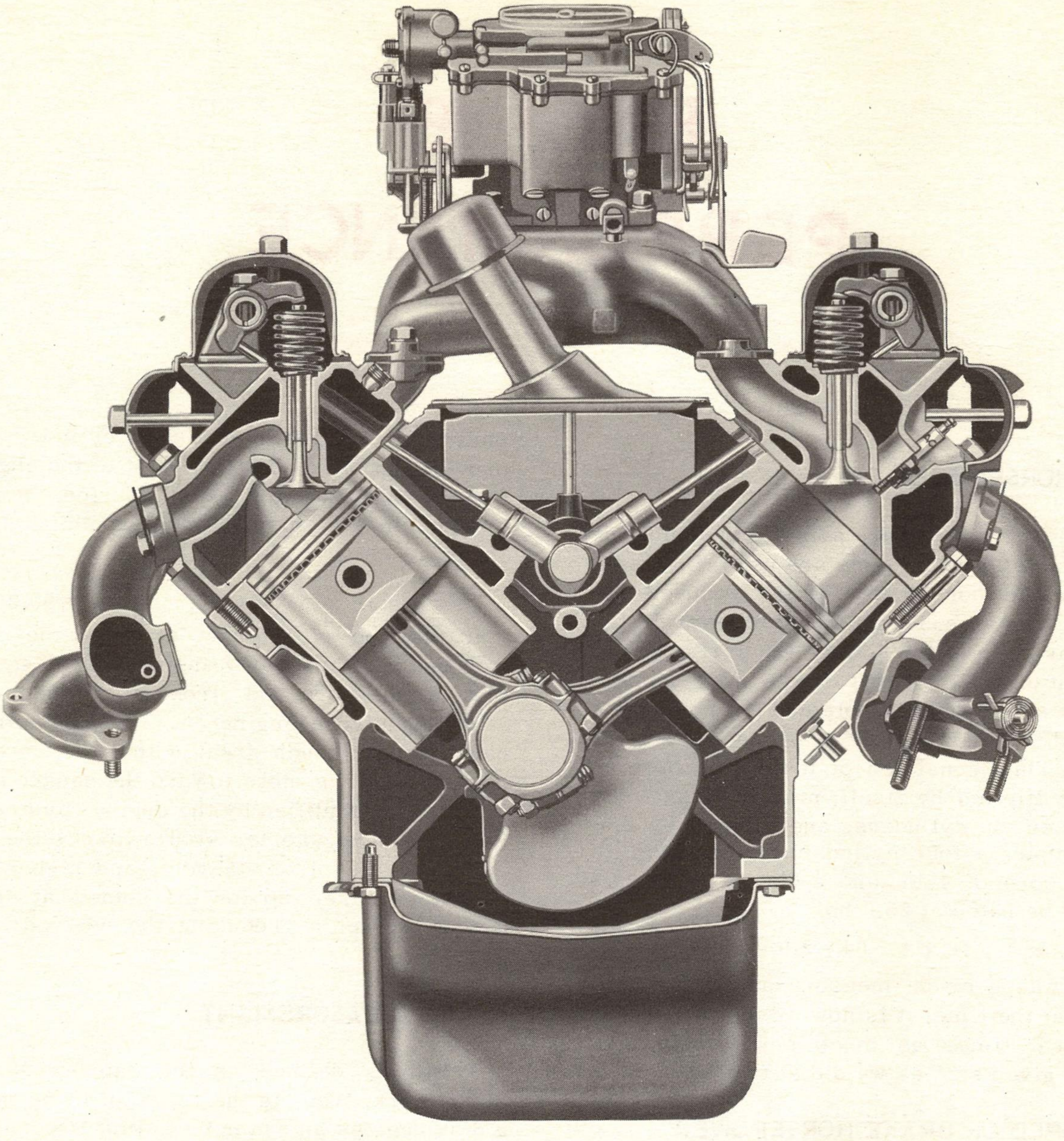
$4 \times 4 = 16 \times .7854 = 12.5664 \times 4 = 50.2656$

It may be of interest at this time to note that many of the early engines were "square," that is, the bore and stroke were about equal. The long stroke engine came along later, and had a stroke much greater than the bore. The current trend is more toward the square engine again as exemplified by the engine illustrated in Fig. 9-1. The shorter stroke lowers the speed at which the piston travels, and higher compression makes up for the somewhat shorter power stroke in producing the desired horsepower.

POWER MEASUREMENT

Power is defined as the rate or speed of doing work. Work is the action of force through a distance. As an example: lifting 10 pounds to a height of four feet performs 40 foot pounds (ft. lbs.) of work. Lifting 20 pounds two feet would be an equal amount of work. Another factor is the time required to accomplish the work. If we lift the 10 pounds four feet in two minutes, our power would be 20 ft. lbs. per minute (ten pounds times four feet, or 40 ft. lbs., divided by two minutes would be 20).

One horsepower is defined as the amount of power required to lift 33,000 pounds one foot in one minute. This unit of measurement was set up by an engineer named Watt who found that a strong horse could hoist 366 lbs. of coal up a mine shaft at the rate of one foot per second. In 60 seconds, or one minute, the horse would have raised the 366 lbs. 60 feet. This would be equivalent to raising 21,960 lbs. one foot in one minute. Mr. Watt decided that 50%



9-1. Cross section of modern short stroke V-8 engine as built by Buick.

added to this figure, or raising 33,000 lbs. one foot in one minute, would represent one horsepower.

The developed or brake horsepower of an automobile engine is the actual power developed by the engine. The horsepower is measured by means of a dynamometer or a device known as a Prony brake.

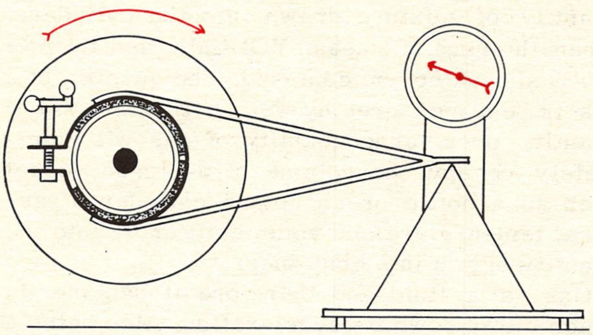
PRONY BRAKE

One method of measuring the amount of power developed by an engine is the Prony brake test. A pulley is mounted on the engine crankshaft and a brake band applied to the pulley. A lever is attached to the brake band and the other end of the lever rests on a platform scale. See Fig. 9-2. With the engine running, the brake band is tightened which causes the lever to press on the scale. The tighter the brake band is adjusted, the more pressure will be indicated on the scale. The speed of the engine, the size of the pulley, the length of the lever and the force or weight indicated on the scale can then be used to calculate the developed horsepower.

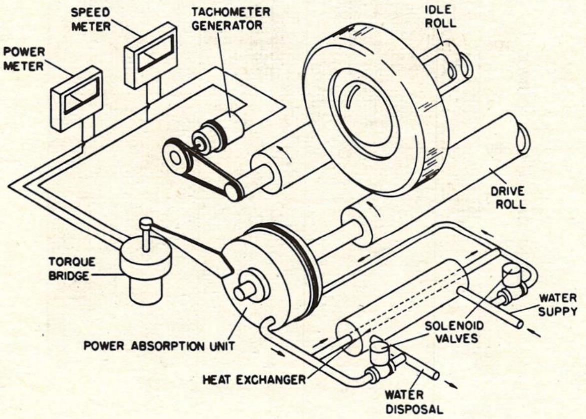
DYNAMOMETERS

Another instrument for measuring the developed horsepower is known as a dynamometer. This instrument consists of a resistance creating device, such as an electric armature revolving in a magnetized field. Or a paddle wheel revolving in a fluid may be used to absorb the energy. The engine is connected to the dynamometer and drives it while suitable gauges register the amount of power produced.

Electric and hydraulic dynamometers are extensively used in automobile factories and experimental laboratories. They are also coming into wide use in automobile service stations. Factory and laboratory installations are usually of the type that connects to the engine alone. Service station types are usually arranged so that the complete automobile can be driven on them and the driving wheels of the car used to turn rollers which are connected to the power measuring and absorbing device. See Figs. 9-3 and 9-4.



9-2. A brake band mounted on a pulley attached to the engine crankshaft arranged as shown herewith, provides a means of weighing or measuring the amount of power produced by an engine.



9-3. The essential parts of a chassis dynamometer are shown here in diagrammatic form.

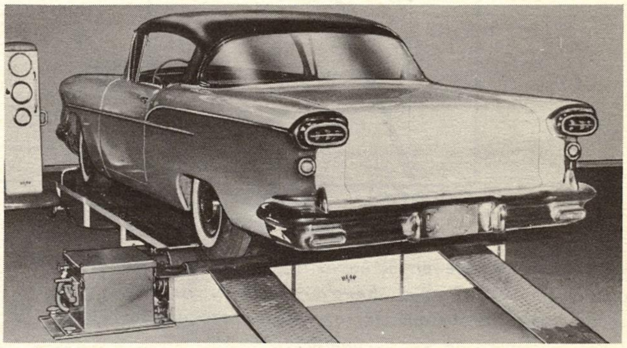
INDICATED HORSEPOWER

There is still another power measurement known as indicated horsepower. This is an engineering measurement and is seldom used outside the factory or laboratory. It is a measurement of the force delivered by the expanding gas to the piston inside the cylinder. It does not take into consideration the friction losses inside the engine. The indicated horsepower is useful to the engineer who is dealing with compression pressure, expansion pressure and mean effective pressure.

CYLINDER PRESSURES

Compression pressure is the pressure existing in the combustion chamber when the piston is at the limit of its travel into the cylinder on the compression stroke. The mechanical condition of the engine and the compression ratio, which will be taken up herein, will cause this pressure to vary and there is no set figure for it.

The expansion (or explosion) pressure is at a peak immediately after the mixture is fired in the cylinder. This pressure is much greater than the compression pressure, but diminishes as the power stroke proceeds.



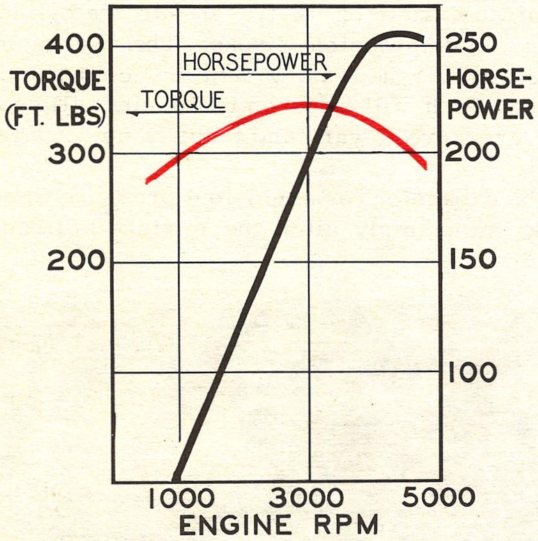
9-4. Service station installation of chassis dynamometer.

The mean effective pressure is an engineering term used to describe the power producing pressures minus the opposing pressures. In other words it is the average effective pressure. In a four cycle engine there is only one power stroke out of every four strokes. The intake, compression and exhaust strokes offer resistance to the power strokes. Also all of these pressures vary from one end of the stroke to the other. By averaging up the pressures on all the strokes and subtracting the three pressures that hinder from the one that helps, we will have the mean effective pressure which is a measure of the engine efficiency.

TORQUE

Another measure of engine efficiency in addition to developed horsepower is the torque rating. It is necessary to distinguish between horsepower--which is POWER--and torque--which is TURNING EFFORT. The two do not coincide as may be seen by reference to Fig. 9-5. This shows that horsepower rises rapidly with the engine speed up to about 4,000 r.p.m. on this particular engine and then falls off.

Torque, however, is not so much a function of speed and in fact after a short rise, starts to fall off. The falling off of torque as the speed increases above a certain point is caused by the inability of the engine to obtain as full a charge of gas in the cylinders as at lower speed. This will be considered further herein.



9-5. Brake horsepower increases rapidly as the speed of the engine increases. Torque, however, reaches its maximum at a speed somewhat below that at which maximum horsepower is obtained.

Torque is measured in foot-pounds. This means that a foot-pound consists of one pound of effort exerted at a distance of one foot from the center of rotation. Likewise, a pressure of one-half pound at two feet, or two pounds at one-half foot would be the same thing or one foot-pound.

Reference to Fig. 9-5 indicates that this particular engine develops its maximum torque of about 350 ft. lbs. at about 3,000 r.p.m. In other words, this would be a force of 300 pounds at a distance of one foot from the center of shaft rotation. Likewise, it would be a force of one pound at a distance of 300 ft. from the shaft center.

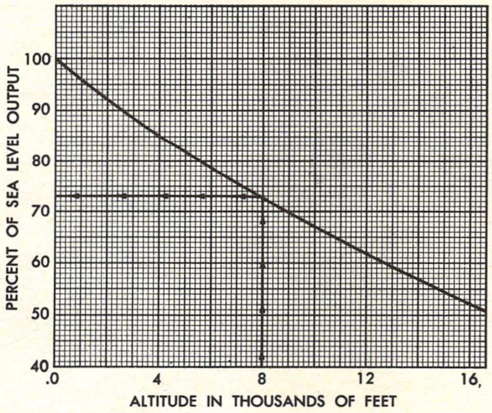
VOLUMETRIC EFFICIENCY

The particular engine represented by the curves in Fig. 9-5 develops maximum torque at about 3,000 r.p.m., which simply means that the engine "breathes" best or has the highest volumetric efficiency at that speed. A maximum amount of explosive gas is being drawn in and utilized to best advantage. At higher speeds, less mixture is being drawn in for several reasons: the amount of time available for filling the cylinder is less and the inertia of the gas as well as the friction of the gas flow is increased.

Furthermore, the atmospheric pressure and the temperature of the gas will influence the quantity of mixture drawn into the cylinders. When thinking of gases, VOLUME and QUANTITY should not be confused. The quantity of a gas is best measured by weight. Either a small quantity or a large quantity of gas will completely occupy the volume of a closed vessel such as a bottle or an engine cylinder. Pressure, temperature and volume all enter into the quantity of gas in a container.

Gas is a fluid and therefore it has inertia which slows down its acceleration. Also being a fluid, it develops friction in the carburetor, intake manifold, as it passes through the valves, etc. All of this tends to restrict the quantity of gas that will be drawn into the cylinders as the speed of the engine increases.

Furthermore, air weighs less when heated and expanded so the quantity is thus decreased. Also the atmospheric pressure will vary with the altitude and barometric pressure so there will be less pressure at high altitude to push the gas into the cylinders. See Fig. 9-6.



9-6. This table indicates that the power output of an engine decreases rapidly as the altitude increases.

SUPERCHARGERS

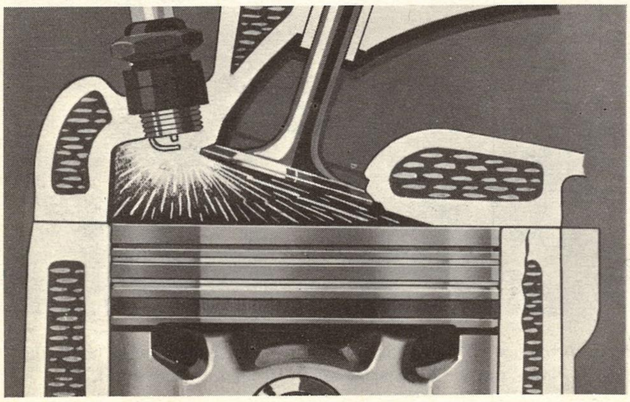
The better the engine "breathes"--or the higher the volumetric efficiency--the more power the engine will produce. That is why superchargers are so effective in increasing engine power. Superchargers or "blowers" are simply air pumps used to force air or gas into the cylinders. They are used extensively on racing engines, and to a limited extent on passenger cars and trucks. They are described and illustrated in the fuel system section of this text.

COMPRESSION RATIO

As mentioned previously, the compression ratio of an engine is an important factor in the amount of power developed by an engine. The degree of compression employed in an engine is known as the compression ratio and is expressed numerically. The design of the engine controls the degree of compression or compression ratio. The basic design can be altered to increase or decrease the compression ratio to a limited extent.

When the piston in the cylinder is at the end of its stroke nearest the crankshaft, it is said to be at "bottom dead center" (b.d.c.). This is true regardless of the position of the cylinders; vertical, horizontal or angular. Likewise the term "top dead center" (t.d.c.) always means the end of the stroke where the piston is farthest from the crankshaft.

With the piston at b.d.c. there is a certain volume of space in the cylinder and combustion chamber above the piston. As the piston moves toward t.d.c. this volume is decreased and the gas within it compressed. See Fig. 9-7. If the volume is compressed into one sixth of the space previously occupied, the compression ratio would be 6 to 1. If compressed into one tenth of the space, it would be 10 to 1.

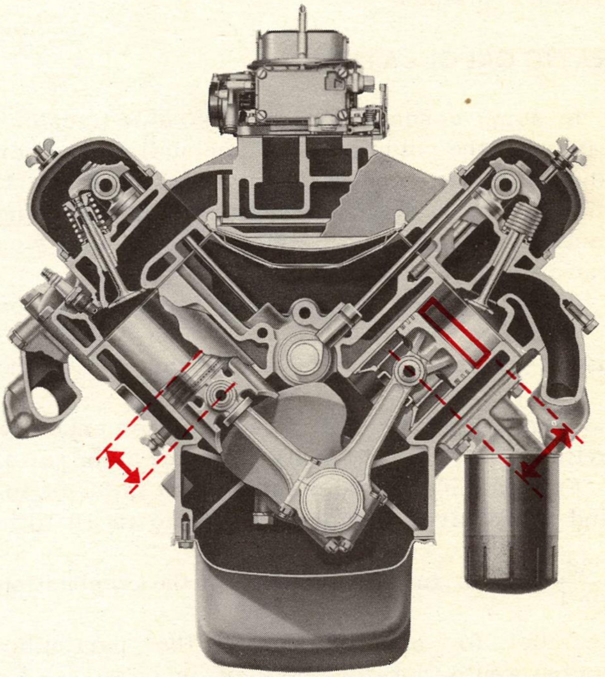


9-7. In this high compression engine, the piston almost touches the cylinder head at the top of the stroke and compresses the gas into the small space in the cylinder head.

Obviously the bore of the cylinder and the size of the combustion chamber will determine the volume within the cylinder. The distance the piston travels in one stroke will determine the degree to which the volume is compressed. Piston travel is determined by the length of the crank arm of the crankshaft to which the piston is attached by the connecting rod.

ALTERING COMPRESSION RATIO

The compression ratio of a given size engine can then be changed by altering the length of the stroke or the volume of the combustion chamber. It is impractical to reshape the original crankshaft, so the usual method of changing the stroke is to install a different crankshaft. It is possible to change the stroke slightly by regrinding the crank throws off center. This is often done in altering engines for racing purposes.



9-8. At left, the normal piston length above the piston pin; at right, the result if altitude pistons are installed. (Piston length increase exaggerated).

Perhaps the easiest method of lowering the compression ratio of an engine is to install a thicker cylinder head gasket (or two gaskets). This of course moves the cylinder head away from the block and the compression ratio is decreased by the increase in volume. To increase the compression ratio the cylinder head is often "shaved" or milled off on the gasket face to bring the cylinder head closer to the block. Excess shaving is liable to result in the creation of a detonation problem by too much increase in compression.

Another method of altering compression ratio is to add or subtract metal to the combustion chamber or piston. Ordinarily the combustion chamber is altered to avoid changing the weight of the pistons. Thus if metal were to be ground out of the combustion chamber, the compression ratio would be lowered. If metal were added by welding or otherwise, the compression ratio would be raised.

The same result can be obtained by adding to or subtracting from the length of the piston ABOVE THE PISTON PIN. See Fig. 9-8. Thus engines operating at high altitudes where the air is "thinner" are often equipped with longer or "altitude pistons."

RATIO CALCULATION

In some cases it may be desirable to calculate what the volume of the combustion chamber should be for a desired compression ratio. It may then be decided which of the foregoing methods to use in altering the compression ratio.

In such cases the following formula may be used: $\frac{B}{C-1} = A$ when A is the volume of the combustion chamber, B is the displacement of the cylinder and C is the desired compression ratio.

For example, if the displacement is 36 cu. in. and the desired compression ratio is 10 to 1:

$\frac{36}{10-1} = 4$ cu. in. The volume of the combustion chamber for one cylinder of that particular engine would therefore be 4 cu. in.

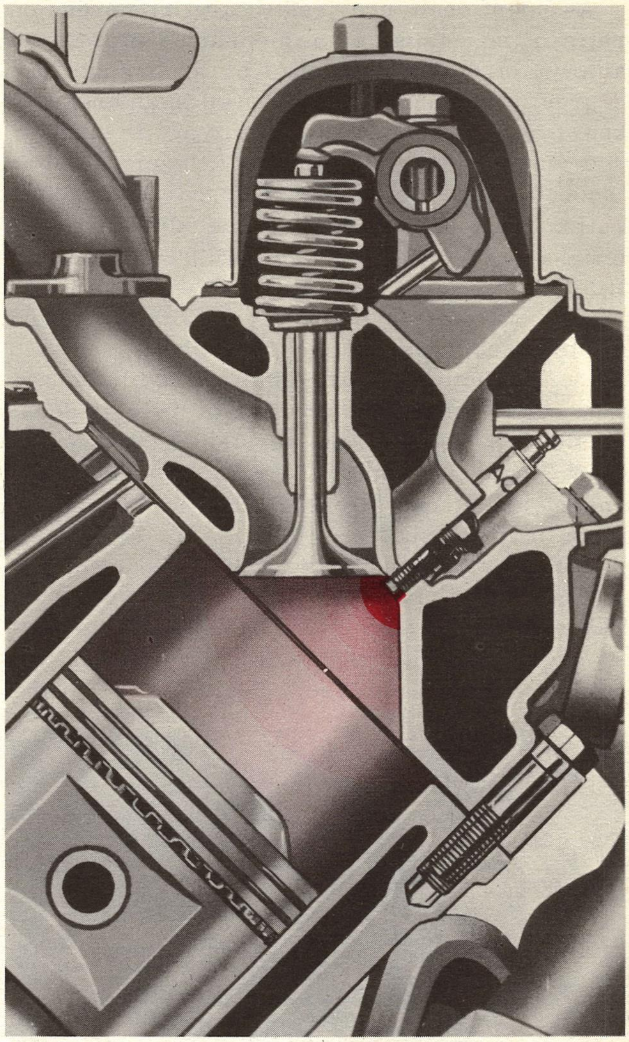
The piston displacement can be calculated from the piston area in sq. in. multiplied by the stroke as previously explained. The volume of the combustion chamber can be determined by the amount of fluid in cu. in. that it will hold.

DETONATION

Previous mention has been made herein of detonation which is called by several names: carbon knock, spark knock, timing knock, ping, rattle, etc. In any case it is an uncontrolled burning and expansion. The so-called explosion of the gas and air mixture in the cylinder of an engine is actually a controlled burning that is so rapid that it is ordinarily called an explosion. It is desirable that the burning action proceed from the point of ignition, which in a gasoline engine is the spark plug, through the cylinder in a constantly widening flame front. See Fig. 9-9. When this flame front is broken or disrupted, detonation occurs.

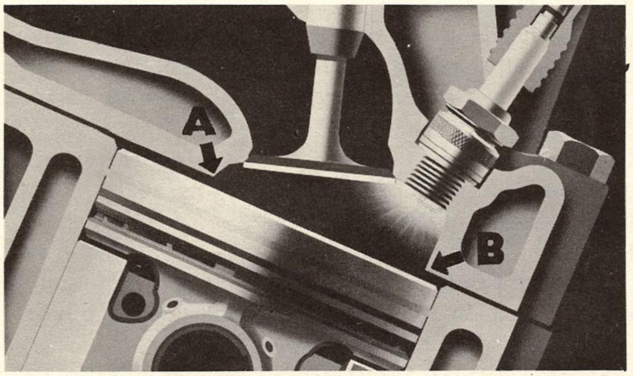
Gasoline is said to have a certain octane rating which is an indication of its tendency to cause detonation. Materials such as tetraethylead are added to increase the octane rating of gasoline. This is explained in the fuels section of this text.

In order to understand detonation better, we must give some consideration to a characteristic of all gases. When they are compressed, heat is liberated; when they are allowed to expand, they cool with great rapidity. That is the theory upon which refrigeration is based. Now of course as we compress the mixture in the cylinder, the temperature of the mixture rises. If an explosive mixture is sufficiently compressed, enough heat will be generated to cause it to ignite. That is how a Diesel engine can operate without spark plugs.



9-9. Normal combustion should occur as shown here with the flame action expanding away from ignition point.

The spark in the cylinder is timed to occur at, or near, top center to cause the expansive force to act on the descending piston. Now if the mixture ignites from the heat of compression before the spark occurs (preignites) there is a tendency to drive the piston back down in the cylinder before it gets to the top of the stroke. This will cause the walls of the combustion chamber as well as the piston to vibrate and create the sound known as detonation.



9-10. Any sharp edge, such as shown at A and B, can become overheated and cause preignition.

Anything that occurs to decrease the volume of the combustion chamber, such as an accumulation of carbon, will aggravate this tendency toward preignition. Other causes are local "hot-spots." This might be the thin edge of an exhaust valve which often operates at a red heat under normal conditions, or an overheated electrode of a spark plug. It might be the edge of a flake of carbon, a sharp edge on a cylinder head gasket, etc. See Fig. 9-10. Preignition is also aggravated by poor cooling water circulation which allows a portion of the combustion chamber to become much hotter than the surrounding area.

Likewise an accumulation of carbon on the inside of the combustion chamber acts as an insulator to slow down the transfer of heat from the burning mixture to the cooling water. This of course increases temperatures in the cylinder. Similarly a coating of carbon on the piston head reduces the cooling action of the oil being sprayed on the underside of the piston from the crankcase.

OPERATIONAL EFFICIENCY

It should be obvious by this time that ignorant tinkering with automobile engines can lead only to distress and poor performance of all kinds. This is apparent from the foregoing study which shows that almost every design feature and individual part in the engine has something to do with its efficiency. For example, the amount of air entering the engine will be controlled by the density of the atmosphere, the size of the opening in the air cleaner and carburetor, the size and shape of the inlet manifold and the volume that can get through the inlet valve.

All these things affect the amount of combustible mixture that enters the cylinders. Then the efficiency of the combustion will depend upon the degree of compression prior to ignition, the temperature of the engine and gas, the time in the cycle at which the explosion occurs, and the ability of the engine to dispose of the burned gas.

Finally, the ability of the engine to utilize the burning and expansion of the gas in creating power will depend upon the frictional losses in the engine, the thermal losses and the mechanical conditions such as leakage from worn out, improperly fitted parts or improper adjustments.

The foregoing is an incomplete listing of the things that enter into the efficiency with which the fuel is converted into usable power. All of the factors will be fully considered herein as the text progresses.

QUIZ - ENGINE PERFORMANCE

1-Brake horsepower is a reliable measure of the power developed by an engine. True--- False---.

2-How is the displacement of an engine determined?

3-Name one advantage of the short stroke engine.

4-The size of the pulley, the length of the lever and the weight indicated on the scale will enable one to calculate the developed horsepower with a Prony brake. True--- False- -

5-Indicated horsepower does not take into consideration the friction losses within the engine. True--- False---.

6-Mean effective pressure is another name for: explosion pressure---, compression pressure---, average pressure---.

7-Define the difference between power and torque.

8-Why does torque decrease above a certain speed?

9-A gas is best measured by: volume---, weight---

10-Given the bore of the cylinder and the volume of the combustion chamber, it is possible to determine the compression ratio. True--- False---.

11-Name three ways of increasing the compression ratio of an existing engine.

12-What is an altitude piston?

13-When a gas is allowed to expand, heat is liberated. True--- False---.

14-Preignition is a method of controlling burning action. True--- False---.

15-Carbon in the combustion chamber interferes with engine cooling. True--- False---.

ENGINE LUBRICATION

Without the aid of friction, an automobile could not move itself. Excessive friction in the automobile however would mean rapid destruction. We cannot eliminate internal friction, but we can reduce it to a controllable degree by the use of friction reducing lubricants.

These lubricants are usually made from the same crude oil from which we obtain gasoline. The petroleum oils are compounded with animal fats, vegetable oils and other ingredients to produce satisfactory oils and greases for automotive use. Lubricating oils and greases are also manufactured from silicones and other materials and have no petroleum products in them.

Lubricating oil in an automobile engine has several tasks to perform:

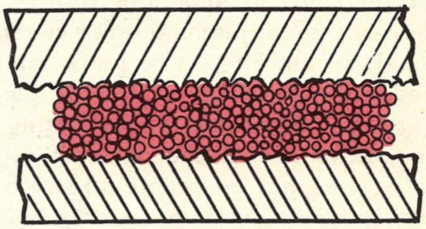
1-By lubrication reduce the friction between the moving parts of the engine, thus:
   A-Reduce the amount of destructive heat generated by excessive friction.
   B-Conserve power that would otherwise be wasted in overcoming excessive friction.
2-By acting as a seal to prevent leakage between parts such as pistons, rings and cylinders.
3-By flowing between friction generating parts and thus carrying away much of the heat.
4-By washing away the abrasive metal worn from friction surfaces.

Furthermore; the engine oil must function whether the temperature is below zero or above 100 deg. F. This is contrary to the nature of petroleum products as they tend to thicken at low temperatures and thin out at high temperatures. The oil therefore goes through many processes during manufacture to reduce this tendency to change viscosity with changes in temperature.

SAE OIL NUMBER

Engine oil is manufactured in various "weights" or "thicknesses," the lighter of the oils having less tendency to stiffen or thicken at low temperatures. These weights are known by numbers assigned by the Society of Automotive Engineers. The lighter the weight the lower the number. Thus SAE 10 engine oil may be recommended for low temperature use, and SAE 30 for use in warmer weather. THE SAE NUMBER OF THE OIL HAS NOTHING TO DO WITH THE QUALITY OF THE OIL.

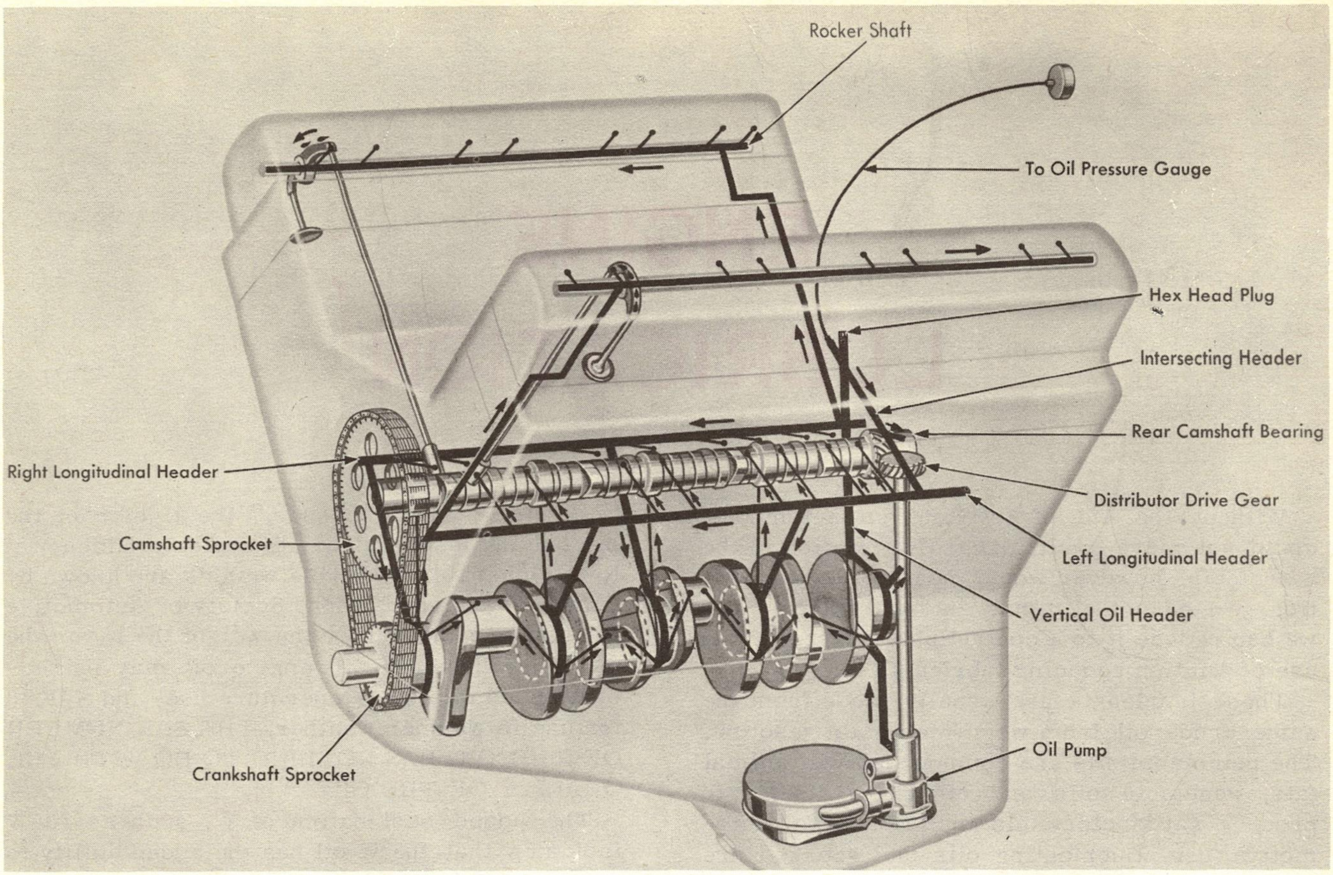
The added designation of W, such as 10-W indicates that the W oil has the added ability to remain fluid or flow at a lower temperature. Thus a No. 10-W can be used anywhere an SAE 10 can be used, but an SAE 10 may not have the fluidity of a No. 10-W at low temperatures. Many oils are branded with both numbers (SAE 10-10-W) and will meet both specifications.



10-1. The oil molecules roll one over the other to reduce friction in a manner somewhat similar to ball bearings.

OIL SELECTION

The car manufacturer recommends the weight of oil to be used in his cars under various conditions. These recommendations are based upon temperatures encountered and the clearances existing in the engine. Thus a new engine built with close fitting parts might use an SAE 20 oil in warm weather, and change to a 10-W in cold weather for light service. In extreme cold a No. 5-W oil might be required for easy starting. Also a No. 20 might be recommended for high speed driving even in cold weather.



10-2. With the full pressure engine lubrication system the oil is fed to practically all of the engine moving parts under pump pressure.

This same engine, after considerable use and wear in the parts might require an SAE 30 oil in warm weather. In any case the car manufacturers instructions should be followed.

In general, the car manufacturer recommends the lightest weight oil that he feels can be used safely under the conditions. This for the reason that a light oil facilitates cold starting and attains circulation sooner than a heavy oil. At the same time it is not desirable to use an oil so light that it cannot maintain a film of oil between the moving parts.

The moving parts in the engine are subjected to speed and pressure as well as heat. The pressure has a tendency to squeeze the oil out, and permit the bearing surfaces to contact each other which would produce friction and cause wear. Even though the metal parts appear to be mirror smooth to the naked eye, they are rough indeed when seen through a magnifying glass. The oil is required to form a film thick enough to hold these surfaces apart. The term "thick" in this case may be a fraction of a thousandth of an inch, but the film may contain several layers of oil molecules.

These layers of oil molecules might be compared to layers of ball bearings of infinitesimal size. See Fig. 10-1. One layer rolls over another with a minimum of friction and these layers hold the two bearing surfaces apart against the pressure tending to force them together.

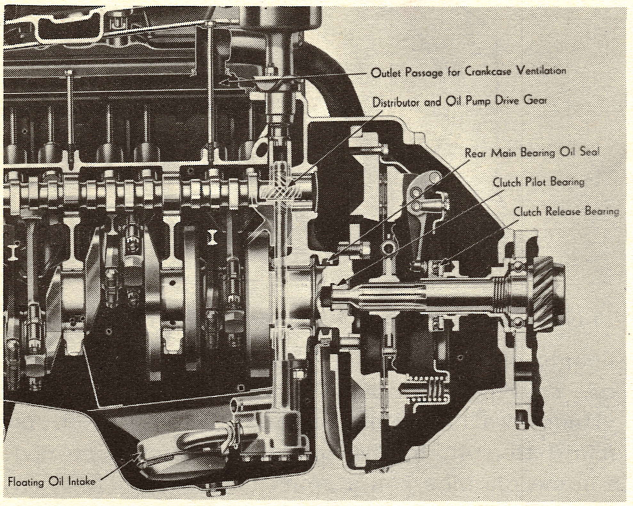
LUBRICATION METHODS

The oil may be supplied to the moving parts of the engine by splashing or by pump pressure, or by a combination of both. Many automobile engines utilize splashed oil--which usually becomes an oil mist--for the lubrication of some parts. The majority of the engine parts are pressure fed, at least to practically all of the bearings. The leakage or "throw-off" from these bearings splashes on the other moving parts inside the engine. A typical system is shown in Fig. 10-2.

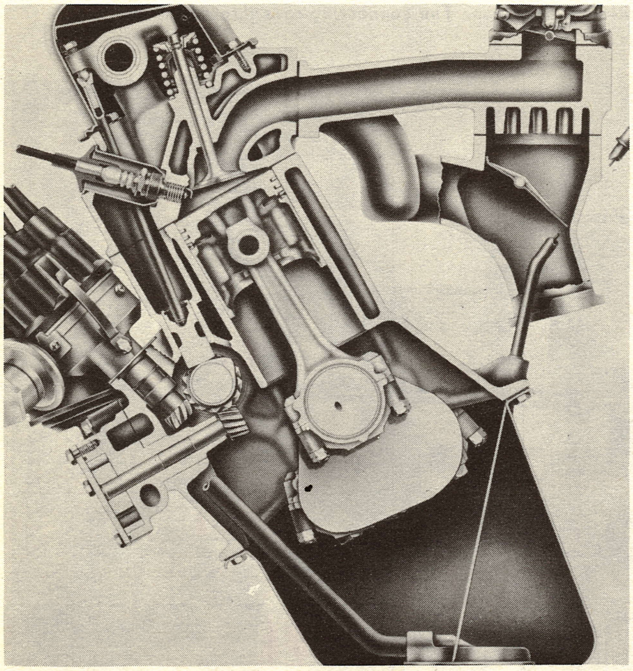
PRESSURE SYSTEMS

As may be seen in Fig. 10-3, the oil pump is located in the sump of the oil pan, and the oil enters the pump through a screen. Sometimes the pump is not located in the sump, and the oil is piped from the screen to the pump as shown in Fig. 10-4. Quite often the intake screen is mounted on a hinged float that stays on top of the oil in the sump as shown in Fig. 10-3. The idea is to keep the pump intake away from any dirt that might settle in the bottom of the sump.

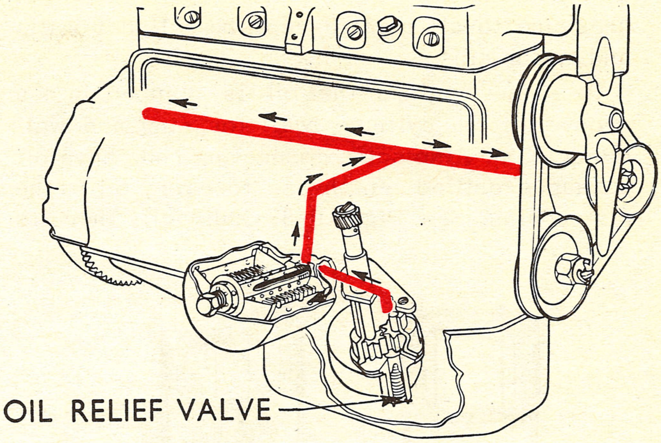
Fig. 10-5 shows the path of the oil from the pump to the oil gallery or distributing tube in the crankcase. The oil is conducted to the main bearings through drilled passages in the crankcase. Passages are also drilled in the crankshaft to carry the oil from the main bearings to the connecting rod journals. See Fig. 10-6. The path of the oil to the overhead valve rocker shaft is shown in Fig. 10-7. Thus oil is carried under


Outlet Passage for Crankcase Ventilation
Distributor and Oil Pump Drive Gear
Rear Main Bearing Oil Seal
Clutch Pilot Bearing
Clutch Release Bearing
Floating Oil Intake

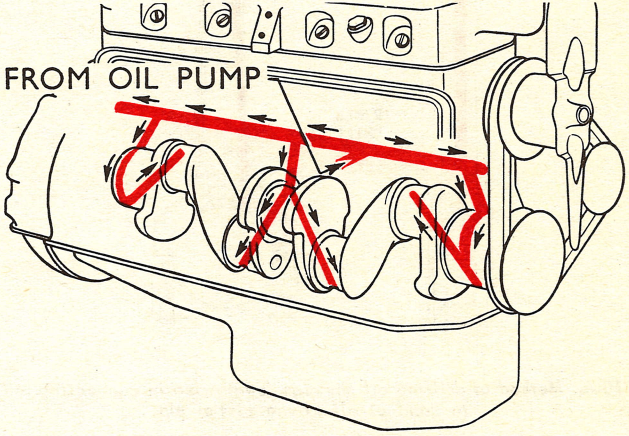
10-3. This Cadillac sump located pump is also fitted with a floating oil intake screen.



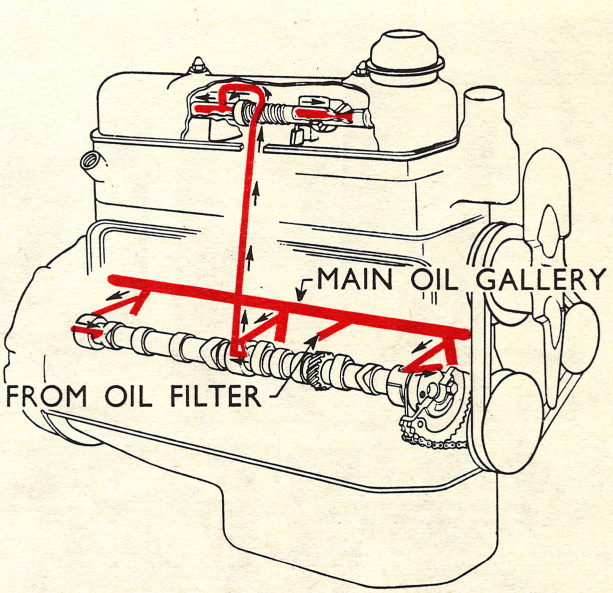
10-4. This Valiant pump is mounted on the side of the engine and is connected to the oil screen by a pipe.


OIL RELIEF VALVE

10-5. In this case, the oil goes through a filter placed between the oil pump and oil gallery.


FROM OIL PUMP

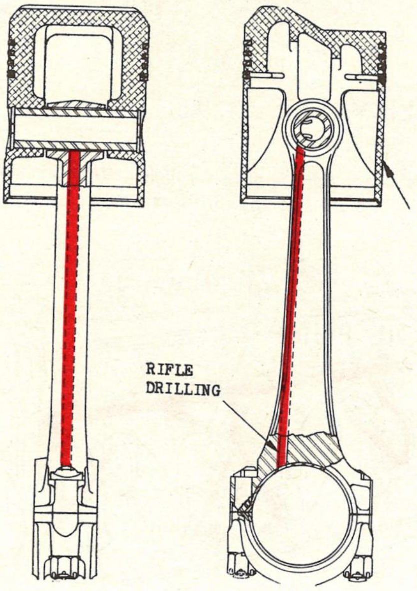
10-6. Oil passages drilled in the crankshaft conduct the oil from the main bearings to the connecting rods.


MAIN OIL GALLERY
FROM OIL FILTER

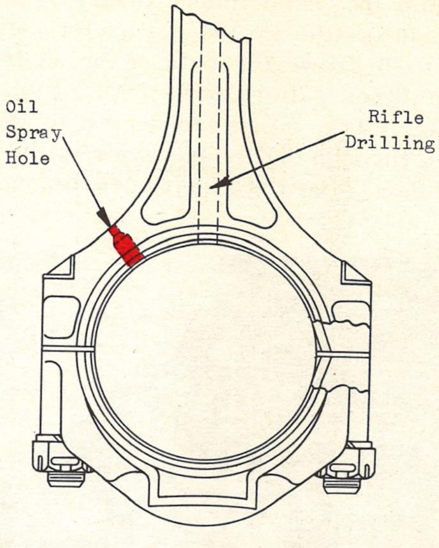
10-7. Oil from the gallery goes to the camshaft bearings and then on to the rocker arm shaft.

pressure to all parts except the cylinder walls and piston pins.

In some engines the oil is pumped into a groove in the cylinder wall for ring and wall lubrication. Also some connecting rods have oil passages drilled lengthwise to carry oil to the piston pins. See Fig. 10-8. Ordinarily there is enough oil thrown off the main bearings and rod bearings to supply lubrication for the cylinder walls and piston pins. See Fig. 10-9. As an aid to splash, the top of the connecting rod in some engines has a spurt hole drilled in it on one side so that a squirt of oil is shot out on the cylinder wall as the hole registers with the oil passage in the crankshaft. See Fig. 10-10.



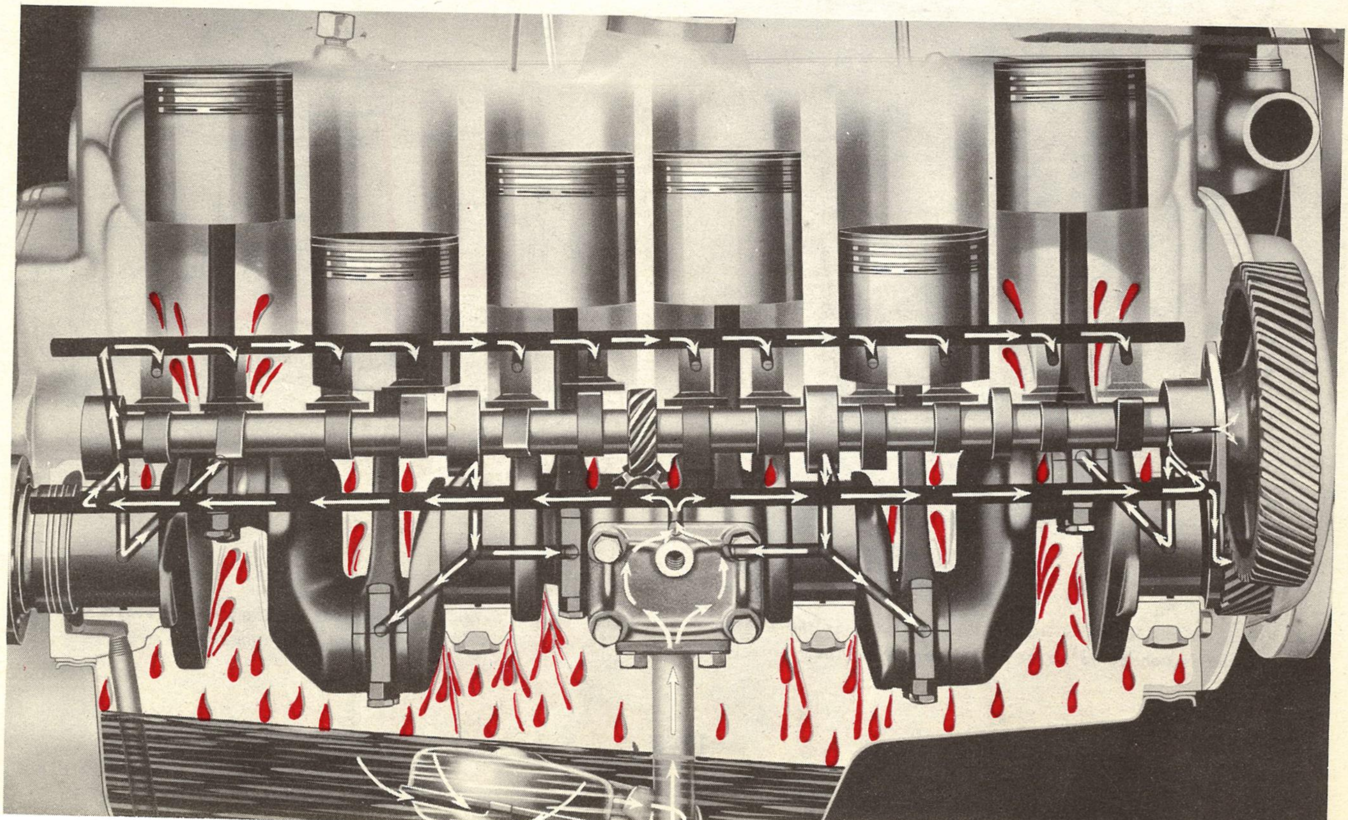
10-8. Method of drilling oil passage lengthwise in connecting rod to conduct oil to the piston pin.



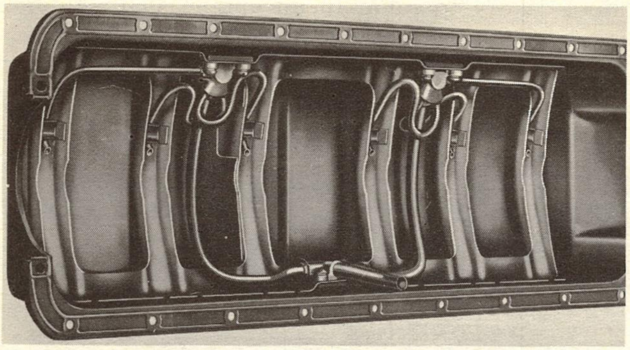
10-10. An oil spurt hole is often aimed at the cylinder wall.

One popular engine used a combination of pressure and splash lubrication for engine bearings. The oil in this case is pumped through pipes into troughs under each connecting rod as

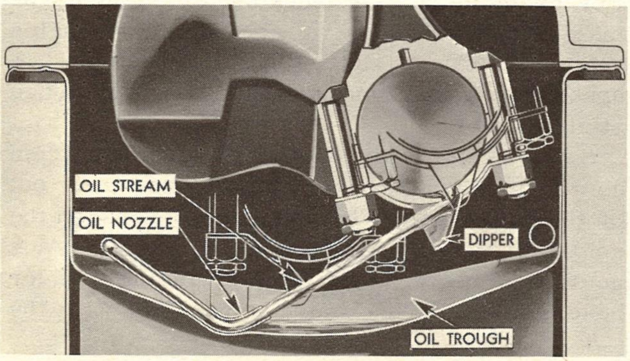
10-9. A limited amount of oil leaks out at the ends of the crankshaft bearings. The connecting rods throw it on the cylinder walls.



shown in Fig. 10-11. These pipes are located and aimed so that a jet of oil is directed into a scoop on the rod bearing as the rod comes around. See Fig. 10-12. The rod also splashes into the oil in the trough and throws it around the interior of the crankcase. The aiming of the jets is important and special gauges are available for locating them correctly.



10-11. In this case the oil is pumped into troughs under each connecting rod bearing and is also squirted at a scoop on each rod. See Fig. 10-12.

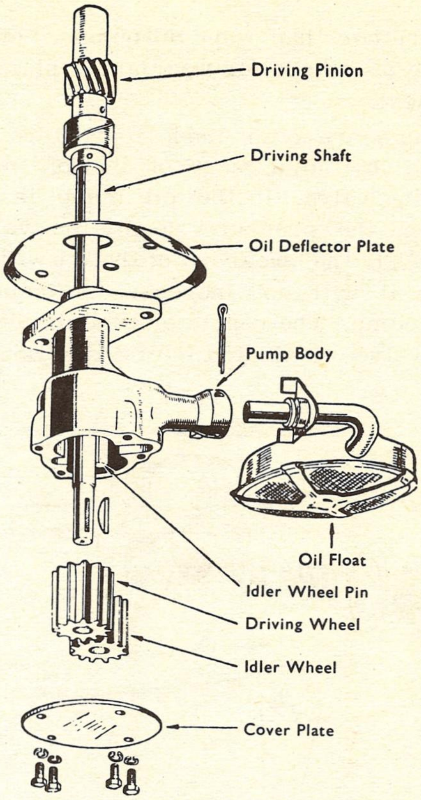

OIL STREAM
OIL NOZZLE
DIPPER
OIL TROUGH

10-12. The oil jets are "aimed," or adjusted so that the oil is squirted directly into the dipper on each connecting rod bearing.

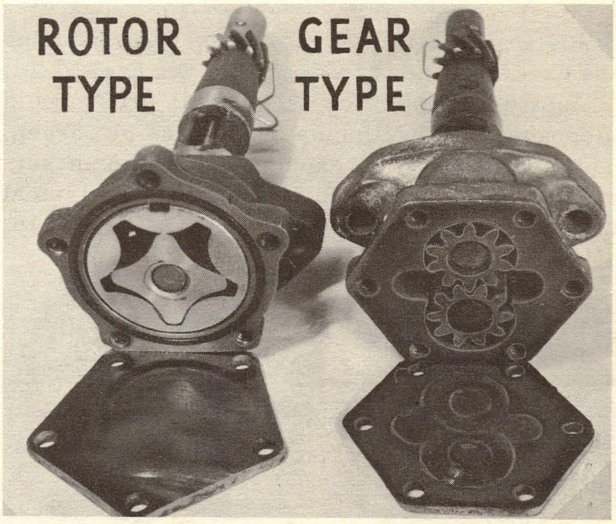
OIL PUMPS

The pumps used to circulate the oil are of the positive displacement type in several designs. Vanes, plungers, rotors and gears are all used to build up the necessary pressure. A representative type of gear pump is illustrated in Fig. 10-13. A comparison between the gear and rotor types is shown in Fig. 10-14. These pumps are always positively driven, usually from the camshaft either by means of gears or cams.

As these pumps handle oil, they are well lubricated at all times and do not suffer from excessive wear. They do, in time develop an excess of clearance and require replacement of parts. The gear teeth or vane contours may wear, and the gear ends and housings may wear. When excessive wear does occur, the oil pressure will drop.


Driving Pinion
Driving Shaft
Oil Deflector Plate
Pump Body
Oil Float
Idler Wheel Pin
Driving Wheel
Idler Wheel
Cover Plate

10-13. Typical gear type oil pump as exploded.

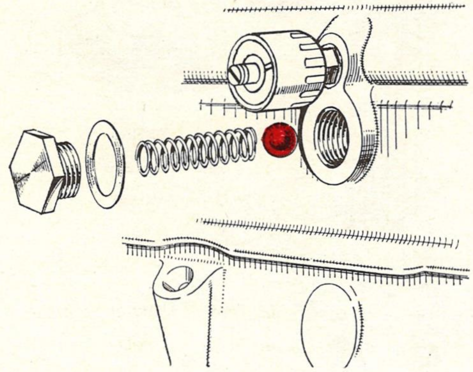

ROTOR TYPE
GEAR TYPE

10-14. Most automobile engine oil pumps are of either the gear type or the rotor type.

OIL PRESSURE

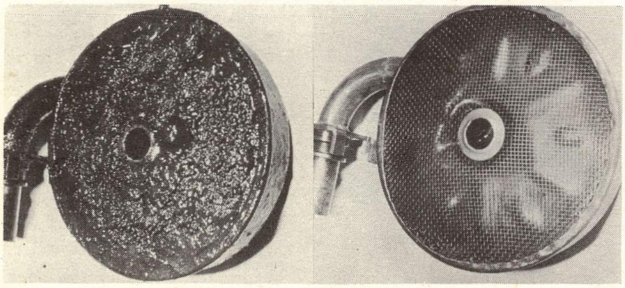
Most cases of lost oil pressure are due to excessive clearance in the bearings of the engine rather than worn oil pumps. Methods of checking oil pumps for wear are explained later in this text.

Attempts are often made to restore lost oil pressure by adjustment of the oil pressure regulating valve. If the oil pump is in good condition, the pressure regulation valve will REGULATE the pressure of the oil within limits, but it will not increase the capacity of the oil pump. The regulator is a simple spring loaded valve which RELIEVES EXCESS PRESSURE in the circulating system by by-passing the excess oil back to the sump. See Fig. 10-15.



10-15. As pressure builds up in the line, the ball is forced back against the spring to uncover a port so that the oil can be returned to the sump.

Another reason for lack of oil pressure is stoppage in the oil pump supply line or screen. This prevents oil reaching the pump in sufficient volume to maintain pressure. A typical case of a stopped screen is shown in Fig. 10-16.

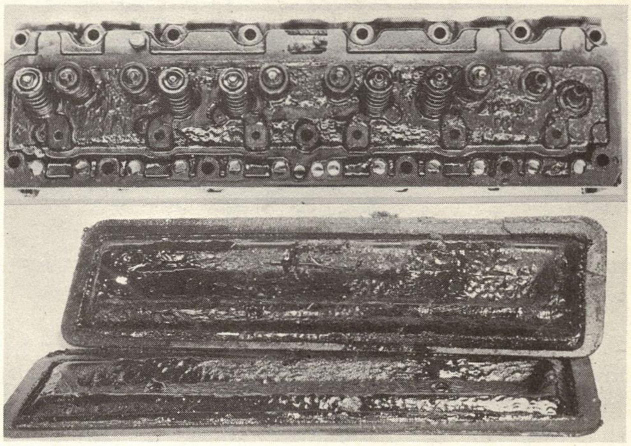


10-16. An accumulation of sludge on the screen as shown at the left will stop the flow of oil and result in burned out bearings.

This is a case of "sludge" accumulation. This same sludge gets into the oil passages and stops them up with the result that a bearing may "starve" for oil and friction will then melt the metal. It is important to prevent the formation of excessive sludge in an engine.

OIL SLUDGE

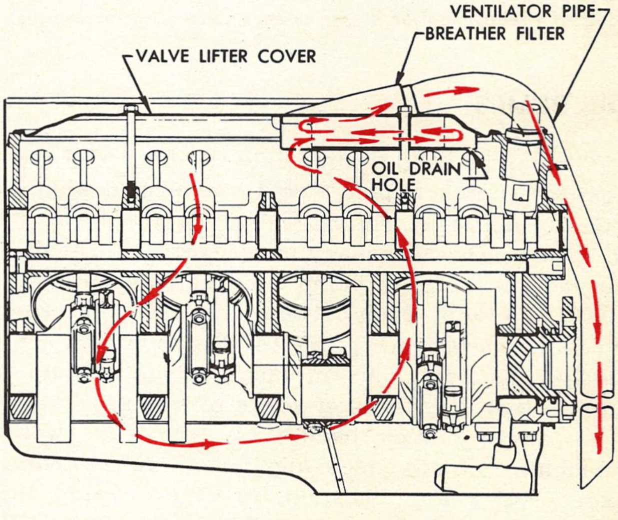
Sludge is a mayonnaise-like mixture of water, oil, dirt and other products of combustion. It is most likely to form in an engine that seldom reaches a satisfactory operating temperature.



10-17. Typical accumulation of sludge on cylinder head and on valve cover plates.

For example; a light truck used for laundry or milk delivery service in cold weather. Such a vehicle ordinarily runs a short distance at slow speed, stops and then runs another short distance at slow speed.

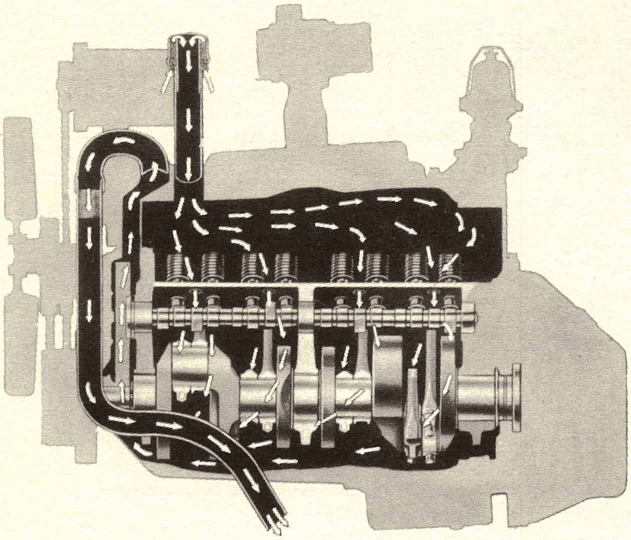
Such operation means that the engine seldom gets hot enough to drive the water and vapor out of the crankcase. The water condenses on the cold walls of the crankcase, or in some cases gets into the crankcase through leaking cylinder head gaskets. This water emulsifies with the



10-18. Air enters through valve lifter cover and after circulating through engine, passes through a filter placed in the outlet pipe.

oil, carbon, dirt, etc., to form sludge See Fig. 10-17.

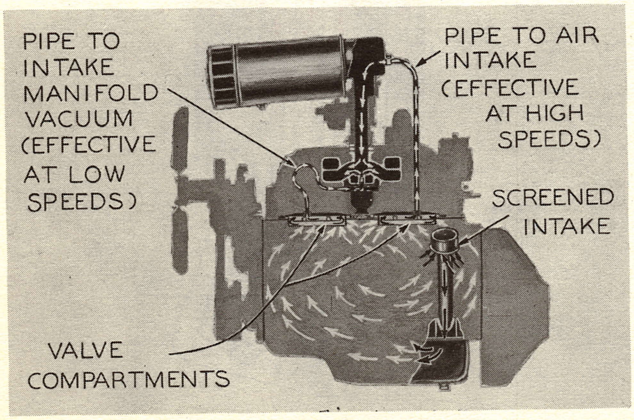
Sludge accumulation can be held down by blocking off part of the radiator so that the engine runs hotter, making sure that the proper thermostat is used in the cooling system, and that the engine oil is changed frequently. Adequate crankcase ventilation is also important. Several types of crankcase ventilation systems are shown in Figs. 10-18 to 10-21. Whatever system is used, it should be kept clean and in good operating condition.



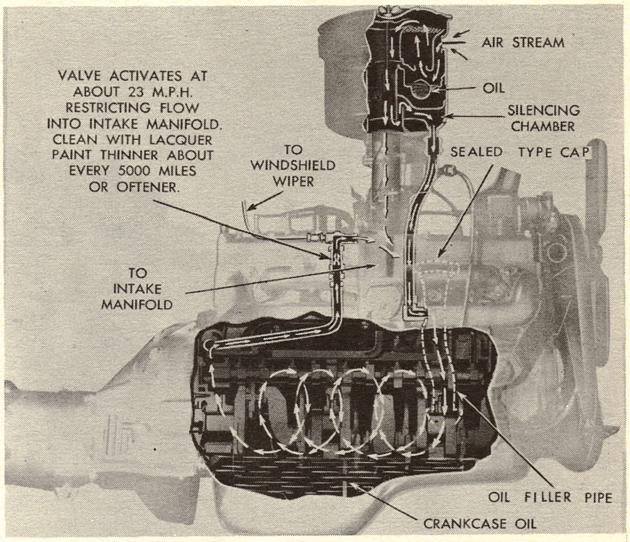
10-19. In this case air is drawn in through the filter on the oil filler cap and drawn out through a special outlet pipe.

ENGINE VARNISH

Another type of engine deposit is known as "varnish" or "lacquer." It is often also called sludge, but it is an entirely different material and forms in a different manner. Varnish or lacquer is formed when an engine is worked hard enough to get good and hot for extended periods of time. The heat causes the oil to break down and some of the elements to separate out and deposit as a varnish-like substance on the metal parts of the engine.


PIPE TO INTAKE MANIFOLD VACUUM (EFFECTIVE AT LOW SPEEDS)
PIPE TO AIR INTAKE (EFFECTIVE AT HIGH SPEEDS)
SCREENED INTAKE
VALVE COMPARTMENTS

10-20. On this system the engine vacuum in the inlet manifold is used to draw ventilating air in through a screen on the oil fill pipe.


VALVE ACTIVATES AT ABOUT 23 M.P.H. RESTRICTING FLOW INTO INTAKE MANIFOLD. CLEAN WITH LACQUER PAINT THINNER ABOUT EVERY 5000 MILES OR OFTENER.
TO WINDSHIELD WIPER
AIR STREAM
OIL
SILENCING CHAMBER
SEALED TYPE CAP
TO INTAKE MANIFOLD
OIL FILLER PIPE
CRANKCASE OIL

10-21. Another method of using intake vacuum to draw in ventilating air through the air cleaner.

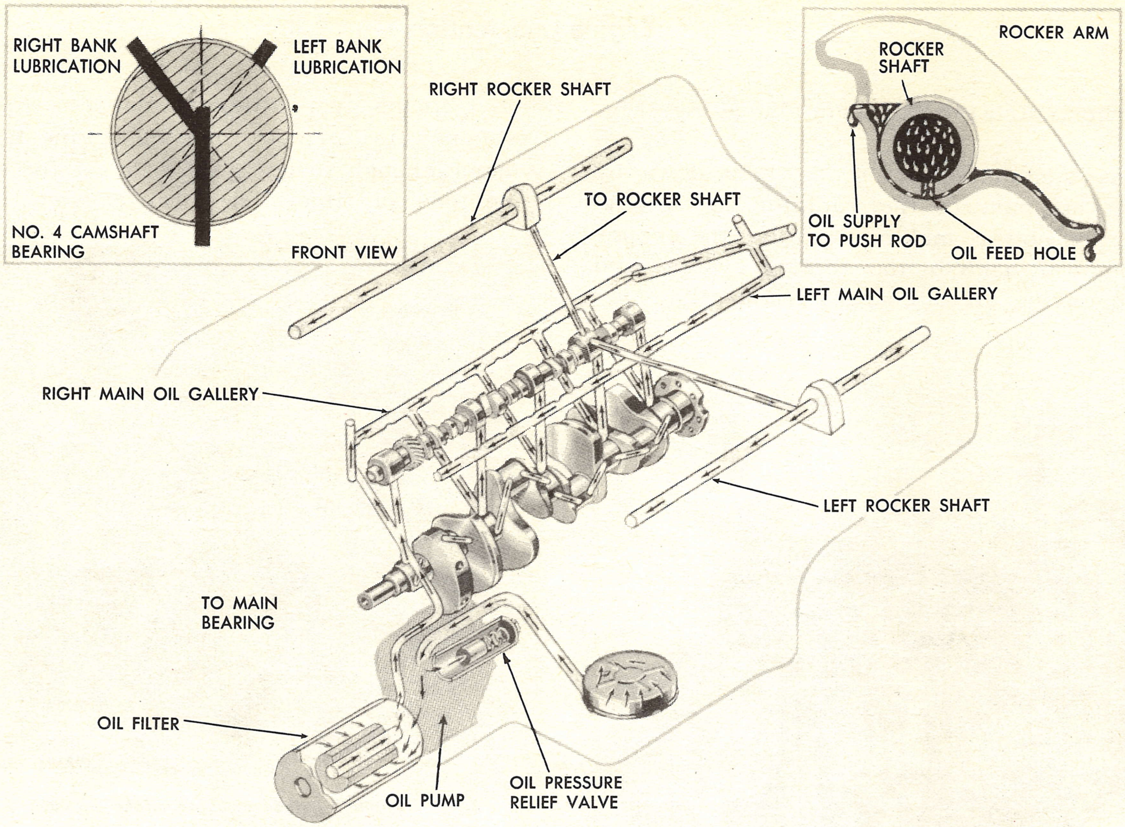
To avoid such deposits, it is necessary to use the best oil obtainable and change oil regularly. It is also essential to make sure that the cooling system is functioning efficiently.

In the preceding text we have emphasized the importance of regular and frequent oil changes. This for the reason that oil costs less than machinery. Changing oil frequently is merely a form of insurance. It is more economical to throw away a quart of oil costing a few cents than to take a chance on damaging an engine worth several hundred dollars.

OIL FILTERS

Another form of engine insurance is the use of a good oil filter. These are made in several types and usually have replaceable filter elements. These elements are made of cloth, paper, felt, etc. and are quite effective in filtering undesirable contaminants out of the oil. See Figs. 10-22 to 10-25. These filters remove carbon, sand, bits of metal and other abrasives that cause wear in the engine.

No matter what type of filter is used, its value depends upon cleaning or replacing the filter element before it becomes choked with dirt. A clogged element can do little good. This is particularly important where the full-flow type


RIGHT BANK LUBRICATION
LEFT BANK LUBRICATION
NO. 4 CAMSHAFT BEARING
FRONT VIEW
RIGHT ROCKER SHAFT
ROCKER ARM
ROCKER SHAFT
TO ROCKER SHAFT
OIL SUPPLY TO PUSH ROD
OIL FEED HOLE
LEFT MAIN OIL GALLERY
RIGHT MAIN OIL GALLERY
LEFT ROCKER SHAFT
TO MAIN BEARING
OIL FILTER
OIL PUMP
OIL PRESSURE RELIEF VALVE

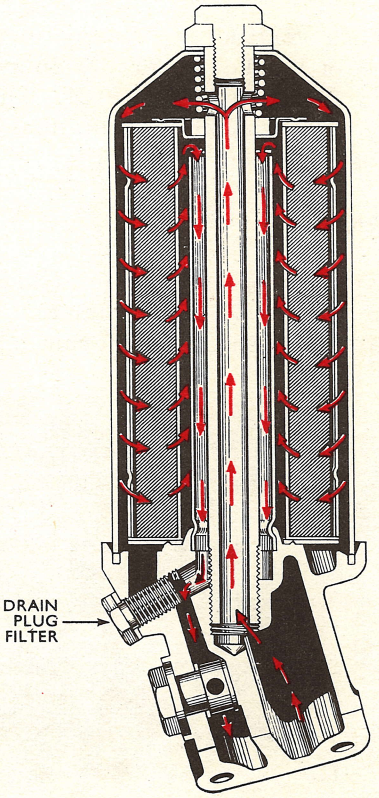
10-22. Filters are often connected directly to the pressure side of the pump to catch any contaminants before they reach the small passages in the camshaft bearings or the rocker arm shaft.

of filter is used, as a clogged filter may shut off the supply of oil. In most cases a valve bypasses the oil when the filter becomes clogged, but it is possible for this valve to fail if enough trash gets in the oil.

OIL ADDITIVES

As previously mentioned, one of the duties of engine oil is to clean the engine operating parts. This is a washing action and of course a light oil is considered a more effective cleanser than a heavy oil. Also some oils contain natural solvents that are more active than others, and are thus more effective cleaners or "detergents." Detergents are also added to oils to give them more cleaning ability.

Many things are added to oils to give them special characteristics. These materials are often referred to as "additives." There are many types of additives, each serving a specific purpose. For example, a "pour point depressant" may be added to cause the oil to flow freely at low temperatures. Also an "inhibitor" may be added which is intended to retard the deterioration of the oil. Another additive is known as a "dispersive." This is expected to prevent contaminants collecting in masses to form sludge. Many other chemicals are used in the refining process, or added to the oil to improve its

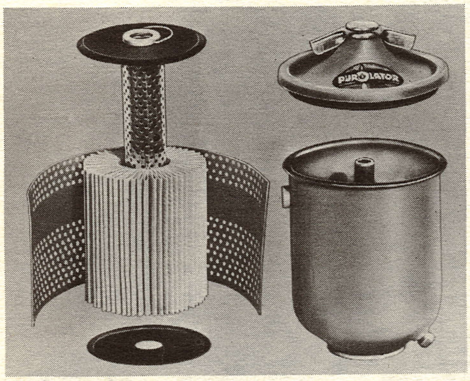

DRAIN PLUG FILTER

10-23. The oil enters and leaves over the entire surface of the filter.

ability to lubricate and clean under all sorts of difficult operating conditions.

CRANKCASE DILUTION

One of the most difficult operating conditions for the engine oil is extended periods of high speed operation which causes the oil to break down as previously described. Another, and perhaps more common, is the intermittent slow speed, or "stop-and-go," type of use which forms sludge in the engine. Another difficulty that goes along with the formation of sludge is dilution of the oil.

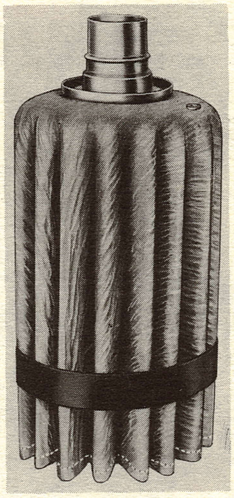


10-24. One type of filter construction.

In cold weather it is necessary to use the choke on the carburetor in order to obtain an explosive mixture in the cylinders. As a result, some liquid gasoline gets into the cylinders and washes past the rings into the crankcase. It mixes with the oil and thins the oil at times until the lubricating ability of the oil is seriously damaged. This lessened lubricating ability along with the oil being washed off the pistons and cylinder walls, results in metal-to-metal contact and rapid wear of rings, pistons and cylinders.

It may be seen then that most of the wear in an engine often occurs in the first few minutes of operation after a cold start before the oil starts to circulate. It is also evident that racing a cold engine to "warm 'er up," will quickly damage it, as there is little or no lubrication of the engine parts. If an engine is operated on dry gas such as propane or butane, there is no dilution of the oil and the oil actually becomes thicker with use rather than thinning out.

This dilution or thinning out of the oil may continue until the crankcase dip-stick indicates that oil is growing in the crankcase. In some cases, a car operated entirely on city streets apparently uses no oil because the level of fluid in the crankcase does not drop. However, if the car is then taken for a longer drive the level will drop rapidly as soon as the engine gets hot enough to boil out the water and gasoline that has diluted the oil.



10-25. Another type of filter element.

QUIZ - LUBRICATION

1-Name four tasks that the lubricating oil in an engine is expected to perform.

2-An SAE 10 oil can be used anywhere that SAE 10-W can be used. True--- False---.

3-Is a light oil always better than a heavier oil? Yes---, No---.

4-What is meant by "OIL THROW-OFF?"

5-Name two ways of oiling piston rings.

6-Oil pumps are sometimes belt driven. True--- False---.

7-What is the most frequent cause of low oil pressure?

8-Name three things found in oil sludge.

9-Sludge and lacquer are not the same thing. True--- False---.

10-Name three engine oil additives.

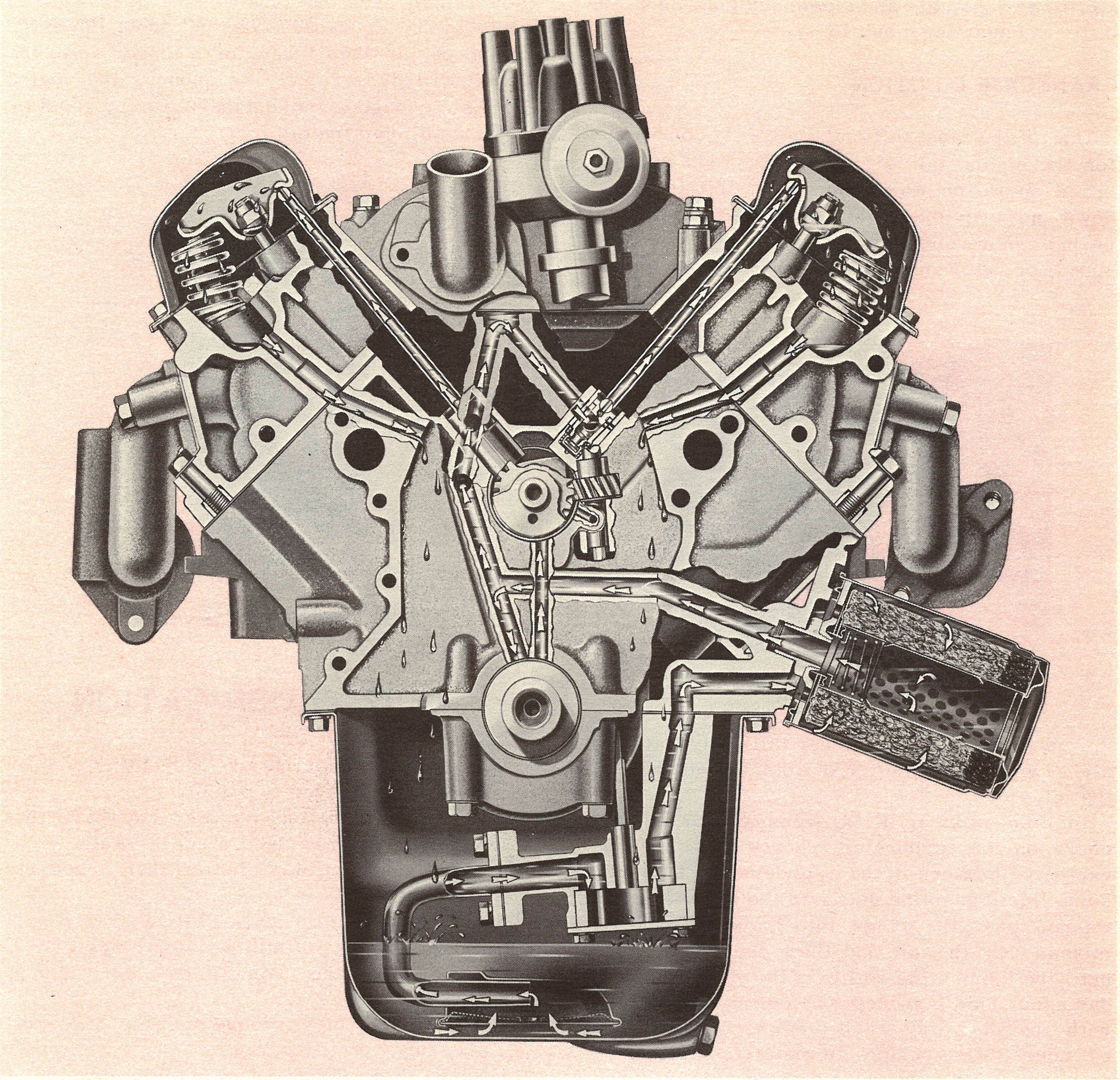
11-Slow speed driving is always desirable in order to maintain the best engine lubrication. True--- False---.

12-How does an oil become diluted?

13-Is dilution better or worse when LPG is used as a fuel? Better---, Worse---.

14-Is it a good idea to run an engine fast as soon as it starts in order to warm the oil up quickly? Yes---, No---.

15-How thick may an oil film be? Less than one thousandth of an inch---, one thousandth---, more than one thousandth---.



Cross sectional view of Ford 332 cu. in. engine, as used in 1962 Fairlane. Oil distribution is indicated by arrows. Note, too, method used to filter lubricant before it is distributed.

ENGINE COOLING SYSTEMS

Some parts of an internal combustion engine would melt from the heat of the burning gas if no cooling system were provided. However, it would probably be more correct to refer to the engine cooling system as a "temperature regulation system." We do not want the engine to run too hot, but neither do we want it to run too cool. We would like to maintain the water jacket temperature slightly under the boiling point of water, or at about 200 deg. F. at all times if that were possible.

The cylinder walls of air cooled engines usually operate at temperatures considerably above 200 deg. This is hot to the touch, but cool in comparison with the heat generated in the combustion chamber of the engine.

As the fuel is burned in the engine, about one-third of the heat energy in the fuel is converted into power. Another third goes out the exhaust pipe unused, and the remaining third must be handled by the cooling system. This third is often underestimated and even less understood.

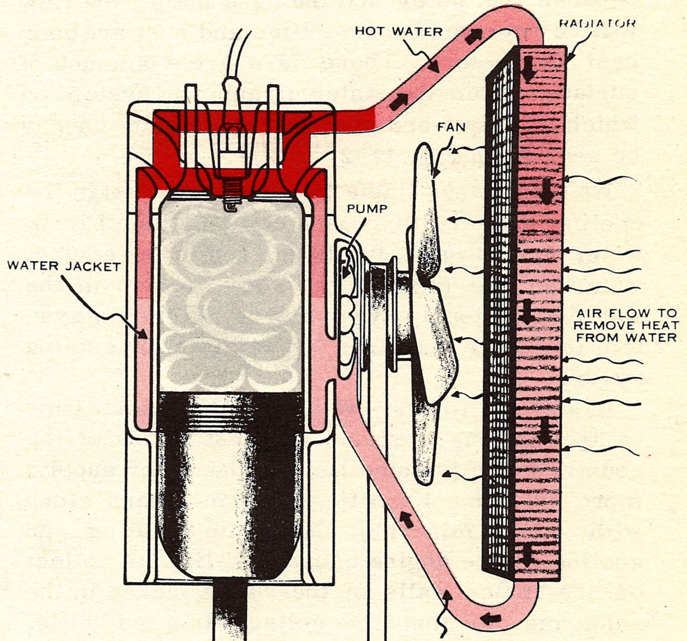
Perhaps it will be helpful to describe it in readily understood terms rather than by reference to so many B.T.U.'s (British Thermal Units). The heat removed by the cooling system of an average automobile at normal speed is sufficient to keep a six-room house warm in zero weather.

This means that several thousand gallons of water must be circulated in the cooling system every hour to absorb the heat and carry it to the radiator for disposal. It also means that many thousand cubic feet of air must flow through the radiator every hour in order to dissipate the heat to the air. It is important at this time to distinguish between heat TRANSFER and heat DISSIPATION.

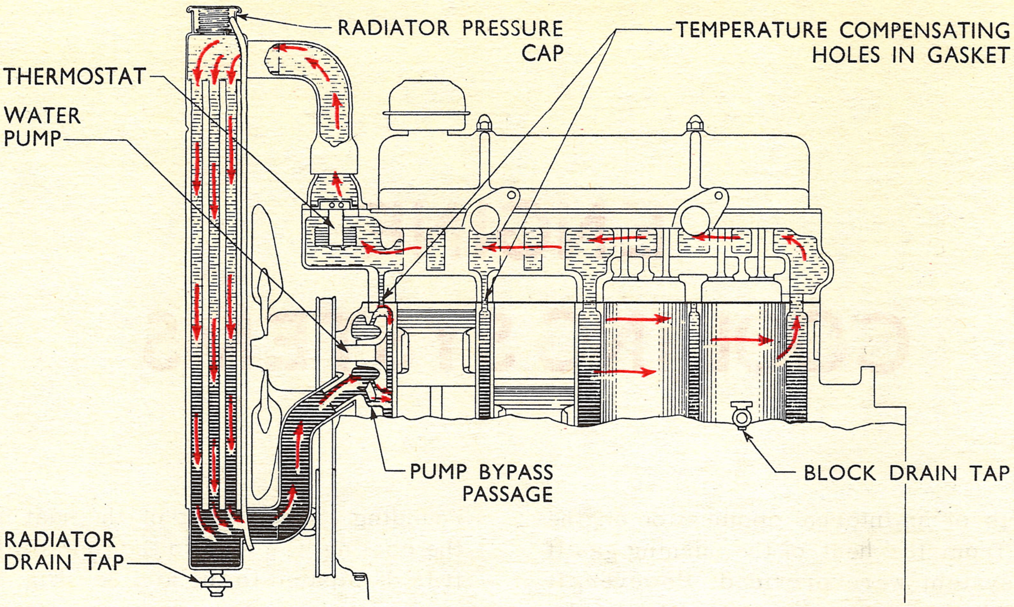
The heat generated by the mixture burned in the engine must be TRANSFERRED from the iron or aluminum cylinder to the water in the water jacket. The outside of the water jacket DISSIPATES some of the heat to the air surrounding it, but most of the heat is carried by the cooling water on to the radiator from whence it is dissipated to the air. See Fig. 11-1.

HEAT TRANSFER

In an automotive engine, heat flows or transfers from the iron or aluminum cylinder to the cooling water, and from the coolant to the copper or aluminum radiator. Iron, aluminum, copper



11-1. Engine temperatures are regulated by transferring the excess heat to the surrounding air.



11-2. With water jackets entirely around each cylinder and valve, there is a great amount of area exposed to the circulating coolant.

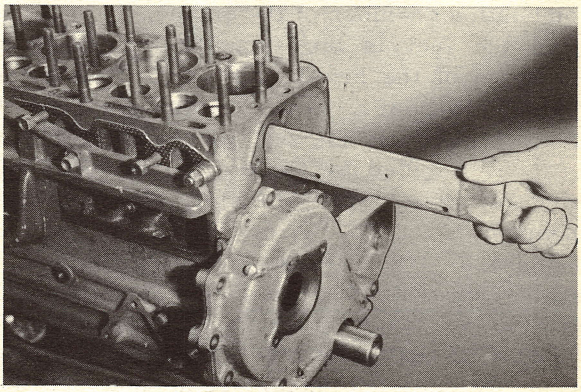
and water are all good conductors of heat, so if they are in good contact with one another, the heat will flow readily from one to another. If, however, there is a coating of lime or rust between the water and the bare metal, the flow will be retarded because lime and rust are poor heat conductors. There is a great amount of surface within the water circulation system on which this lime and rust can accumulate as may be seen from Fig. 11-2.

We are always liable to have some rust in the cooling system. Rust is a combination of iron, water and oxygen. We have iron in the engine, water in the engine, and some oxygen in the water. Additional oxygen enters the cooling system in the air that finds its way into the cooling system.

In addition to rust, we usually have some lime in the cooling system. In most parts of the country there is some lime in the water supply; more in some localities than in others along with other minerals. Alternate heating and cooling of the engine causes the lime to collect on the inside walls of the water jacket in the same manner that lime collects in a tea kettle.

This rust and lime in the cooling system combines with a small amount of grease or oil, which often acts as a binder to hold the lime and rust to the iron, and soon we have a coat of insulation on the inside of the water jacket. Grease or oil gets into the cooling system from water pump lubricant, leaking cylinder head gaskets, etc.

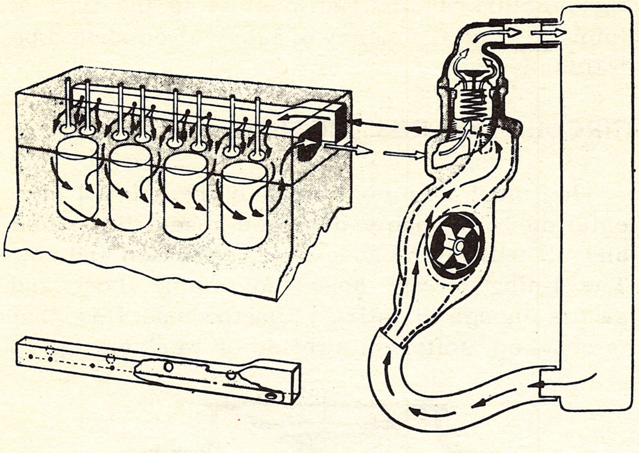
In addition to coating the inside of the water jacket, this scale will collect in corners or pockets of the water jacket where the water circulation is sluggish. This often causes "hot spots" which in turn cause distortion of cylinders and valve seats. Another cause of hot spots, particularly around the exhaust valves, is the stoppage or corrosion of water distributing tubes which are added to improve cooling of the exhaust valves. See Fig. 11-3.



11-3. Water distributing tubes may be inserted in the cylinder block behind the water pump and along side the valves.

These tubes are intended to accelerate the circulation of the cooling water around the exhaust valve seats. See Fig. 11-4. If they rot out or get stopped up, the valve seats may overheat and crack. This type of overheating can and does occur without any indication of overheating on the temperature gauge. The gauge is located at one spot in the water jacket, and the overheating condition is localized in another spot.

The scale that collects in corners and narrow passages is also a deposit point for bits of rubber from the inside of the hoses, and other trash that finds its way into the cooling system. The result is a mass of insulating sludge and scale which does considerable harm to the engine. Such accumulations can be avoided by proper maintenance of the cooling system, the use of inhibitor solutions, electrolytic devices and periodic flushing of the cooling system.

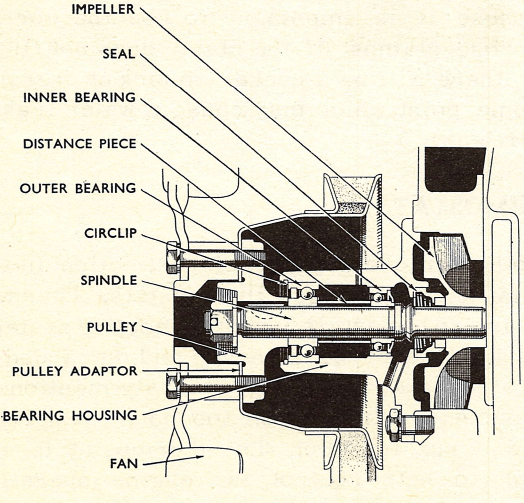


11-4. *The coolant is sprayed around the valve seats by jets from the water distributing tube.*

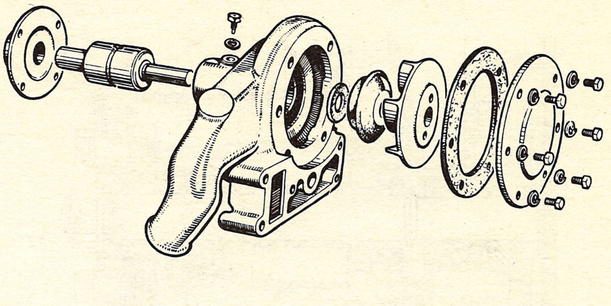
COOLING SYSTEM PUMPS

Automobile engine water pumps are of many designs, but most of them are of the centrifugal type. That is, they consist of a rotating fan or impeller, and seldom are of the positive displacement type using gears or plungers. Many of them are quite efficient, but some of them are more on the order of agitators or circulators. Sometimes the fan is combined on the same shaft with the water pump. A water pump and fan combined on one shaft is shown in Fig. 11-5.

An exploded view of a typical water pump assembly with all the parts in proper relation to each other, is shown in Fig. 11-6. Sometimes the vanes on the impeller are straight, but in this case they are curved to accelerate the centrifugal flow of the water. These vanes should not touch the housing, but at the same time should not have excessive clearance. See Fig. 11-7. For this reason, excessive endwise motion of the shaft to which the vane is attached is not permissible.

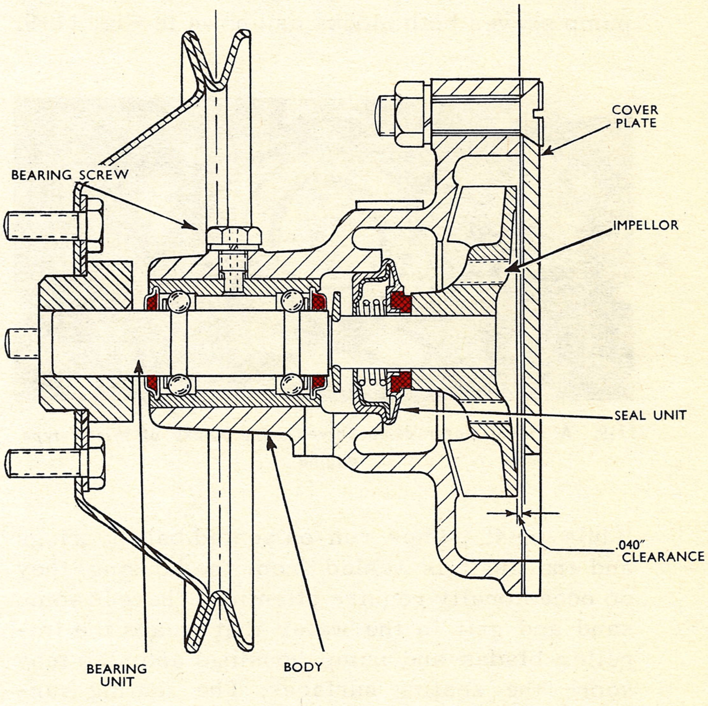


11-5. *A single belt is often used to drive both fan and water pump by placing both on the same shaft.*



11-6. *Construction of a typical separate water pump. Note curved vanes.*

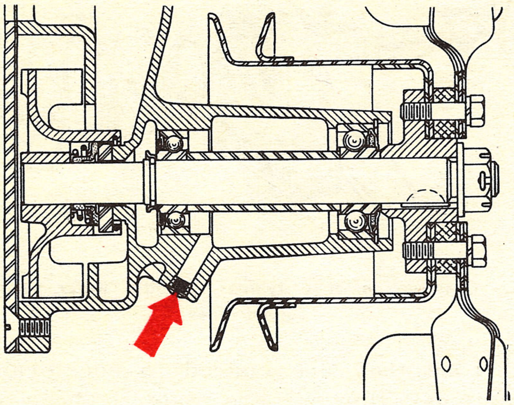
Obviously, such pumps must turn rapidly in order to be efficient. Worn or loose belts will permit slippage which is not readily detected. It is particularly difficult to detect a worn V-belt fan pulley. In case the pulley is suspected, the



11-7. *The shaft ball bearings are sealed at each end to keep lubricant in and water out of the bearings. A spring loaded seal is used to avoid water leakage around the pump shaft. Note clearance between impeller and cover plate.*

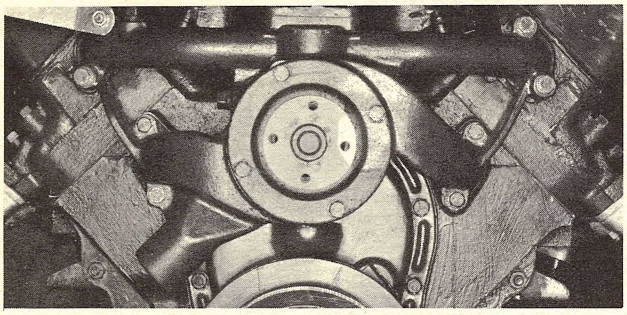
groove can be compared with a new pulley for wear.

Most pumps have a spring-loaded seal to avoid leakage of water around the pump shaft. One such type is shown in Fig. 11-7. This particular pump is fitted with pre-packed ball bearings which are well sealed at each end and therefore periodic lubrication is not required. A somewhat similar pump is shown in Fig. 11-8, but this pump has provision for grease insertion through a plug hole if it should become desirable.



11-8. Provision is made in this design for the addition of lubricant if desired by removal of a screw plug.

V-type engines often have a water pump on each cylinder block. In other cases a single pump serves both blocks as shown in Fig. 11-9.



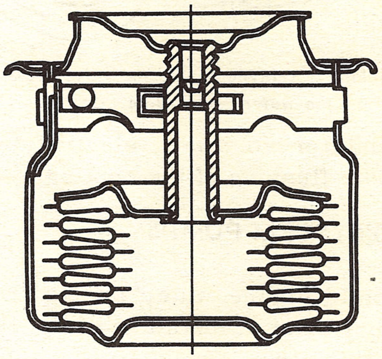
11-9. A single water pump serves both blocks of this V-type engine.

While most pumps run on sealed ball bearings and the shaft is sealed from the housing, they do occasionally require attention. There is some sand and grit in the water that wears the impeller blades and pump housings and also may score the sealing surfaces. The sealing surfaces may be scored enough to leak air if not water. Special reamers are available for resurfacing the seat in the pump housing when the seal is replaced.

If the pump is designed for lubrication, it should not be overlubricated. Excess lubricant may get into the cooling system, and coat the water jacket passages and radiator passages with oil. This causes lime and rust to adhere. The manufacturers' instructions as to the type of lubricant and frequency of lubrication should be followed.

CIRCULATION RESTRICTIONS

The most common cause of restricted circulation is probably damaged hoses. Hot water and oil will often cause hoses to soften and rot. The lining of the hose may come loose and swells enough to entirely plug the hose. Hose that is cracked, softened, swelled or weak enough to collapse from pump suction should be replaced at once. Otherwise bits of rotted rubber will get into the radiator passages and clog them.



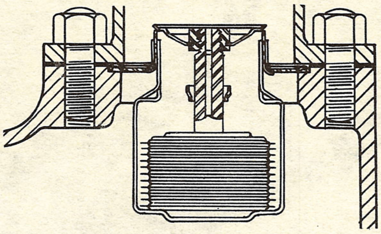
11-10. As shown here, the bellows has contracted to close the valve.

A straight piece of hose should never be used to replace a moulded, curved hose as it will kink and reduce the flow of water. When installing hose it is important to use the correct size hose clamps. If the clamp does not fit the hose, there will be a pucker or lack of pressure at some point which may cause a water leak or an air leak.

THERMOSTATS

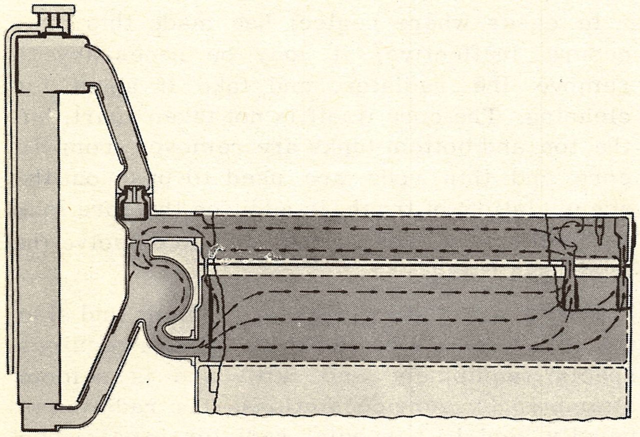
Another frequent cause of restriction in the circulation is damaged thermostats. Thermostats are an important part of the cooling system, and should never be removed and discarded in case of overheating. As previously mentioned, the engine should not run too hot--but neither should it run too cool. The thermostat is essential to help control the engine operating temperature. The construction of a typical thermostat is shown in Fig. 11-10. Thermostats are installed between the water jacket outlet, and the radiator upper tank as shown in Fig. 11-11.

The operation of a thermostat is shown in Figs. 11-12 and 11-13. When the water is cold, the thermostat bellows contracts and closes the valve. This causes the water to be shut off from the radiator, and it then circulates only in the engine water jackets as shown in Fig. 11-12. Thus the engine has a smaller volume of water to heat, and the operating temperature rises more rapidly than if the radiator were helping cool the water.



11-11. Thermostats are often located directly inside the water outlet of the cylinder block.

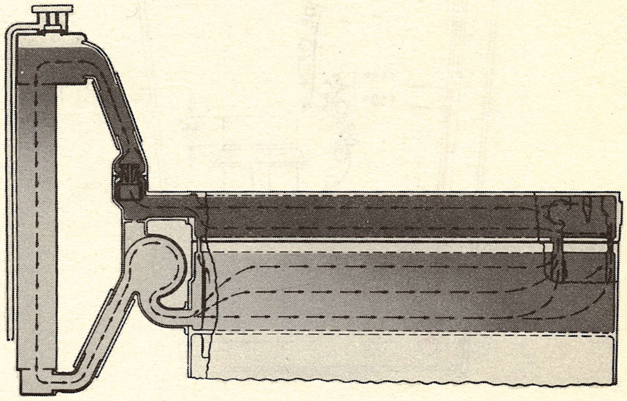
After the water in the block becomes warm enough to expand the bellows (see Fig. 11-14), the valve opens. This allows the water to go to the radiator and be cooled, and thus maintain the desired operating temperature. See Fig. 11-13.



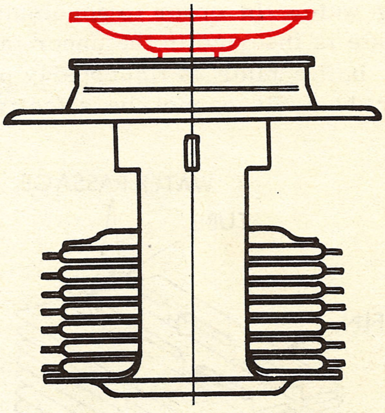
11-12. With the thermostat closed, the water circulates entirely within the engine block thus warming up more rapidly.

Thermostats are calibrated at the time of manufacture to open at the desired temperature and are not ordinarily adjustable in service. The opening temperature is usually stamped on the thermostat. If volatile anti-freeze is used, it is customary to use a thermostat opening at a lower temperature than is the case where the permanent type anti-freeze is used. This for the reason that volatile anti-freeze boils at a lower temperature.

In case the thermostat is not marked for the opening temperature, or in case it is suspected of improper operation, it can be checked by heating in a vessel containing water and a thermometer as shown in Fig. 11-15. By observing the temperature at which it starts to open, the range of operation will be determined. Special testing equipment made for the purpose is also available.



11-13. When the water becomes warm enough to open the thermostat, the water circulates through it into the radiator and thus normal cooling action is obtained.

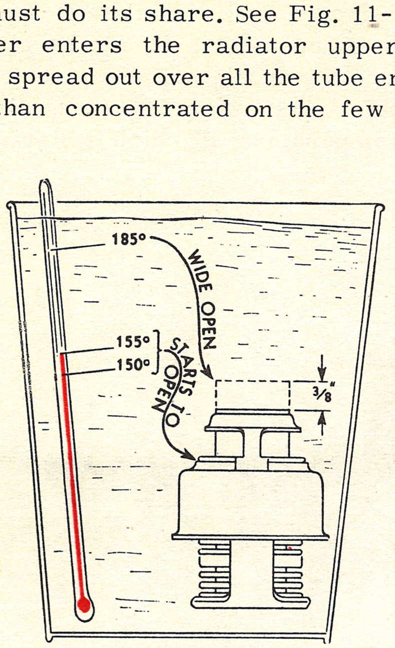


11-14. Thermostat in open position.

Visual inspection will often disclose a warped, bent or permanently expanded bellows or valve. In such cases the thermostat should be discarded. Other types of thermostats containing cartridges, springs, etc., can be checked as outlined. They should be discarded if any doubt exists as to their condition.

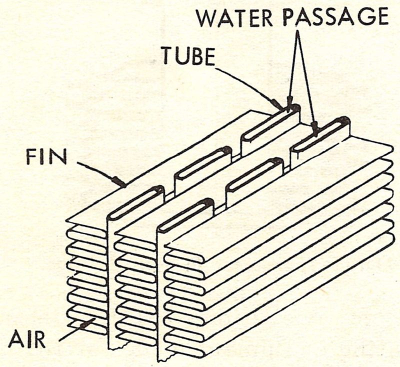
RADIATOR CIRCULATION

In order for the water to circulate in the radiator, the passages must be unrestricted throughout the radiator. These passages are narrow and there are many of them, each of which must do its share. See Fig. 11-16. When the water enters the radiator upper tank, it must be spread out over all the tube entrances, rather than concentrated on the few near the incoming water. In order to accomplish this, a baffle plate is inserted in the upper tank.



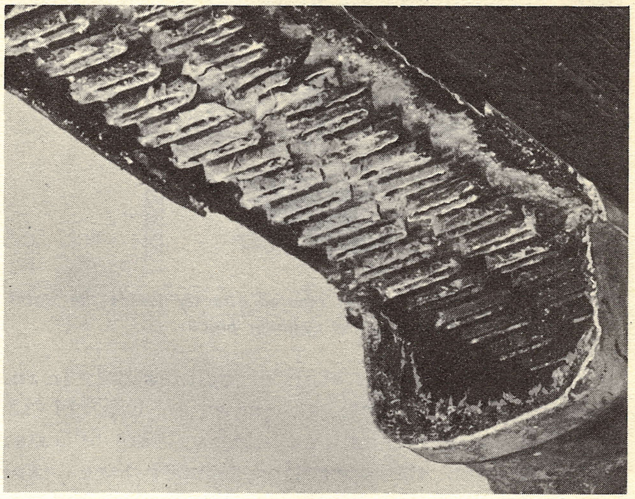
11-15. Simple method of testing operation of a thermostat. (The figures and dimensions shown are typical and do not apply in all cases).

If this baffle plate is improperly positioned, loose or bent, it cannot be effective in distributing the water. Sometimes it will throw the incoming water out of the overflow pipe, particularly at high engine speeds. Baffle plates should therefore be checked as the objective is to spread the water out as thin as possible over as much radiation surface as possible, in order to increase heat radiation to the air. Manufacturers find it desirable to use metal as thin as practical to speed radiation so radiators are fragile.



11-16. Typical radiator core construction.

As the radiator water passages must be small in size they provide an ideal lodging place for bits of rubber, lime, scale and any other trash that finds its way into the cooling system. See Fig. 11-17. This trash is difficult to remove as the radiator core is fragile and cannot be handled roughly. Chemicals and power flushing are often effective.



11-17. Part of the bottom tank is here cut away to show an accumulation of trash.

In cases where neglect has made this procedure ineffective, it may be necessary to remove the radiator, and take it apart for cleaning. The core itself is not taken apart, but the top and bottom tanks are removed from the core and thin rods are used to push out the accumulation of trash. In addition the core may be boiled in a tank of chemical to dissolve the scale and trash.

Taking a radiator apart for cleaning and also the repair of major leaks or damage requires special equipment and skill, and is seldom attempted by service stations. The radiator is usually sent to a special radiator repair shop for service. Minor leaks or damage near the surface can be repaired in the average repair shop by soldering as required.

Many service stations are equipped with testing devices to determine whether or not the water passages in the radiator are stopped up. Such equipment is known as a "flow-meter" and it measures the quantity of water that will flow through the core in a given time. Charts are available which show the proper capacity of the radiator being tested. The test can be made with the radiator on or off the car, and the same equipment is also used as a test after the radiator has been cleaned and repaired.

and lowering the protection. This evaporation loss is greatest under prolonged high speed driving conditions or extended idling periods in heavy traffic.

RUST INHIBITORS

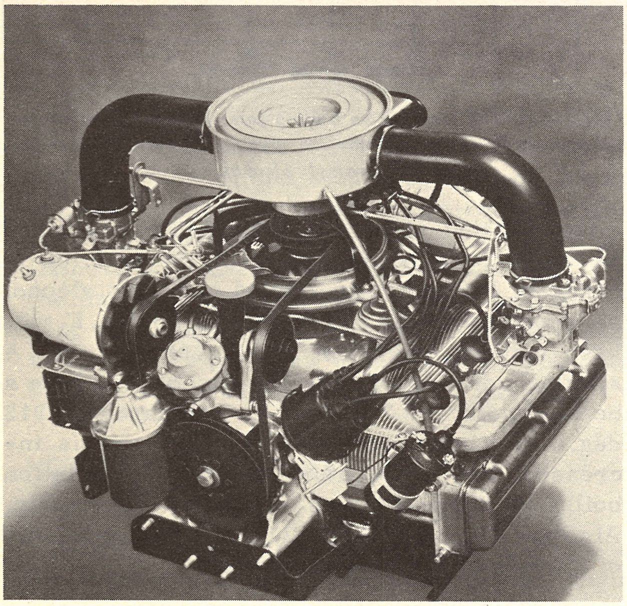
In order to reduce the formation of rust, commercial anti-freeze contains an inhibitor designed to prevent such corrosion. Some products also contain anti-foaming agents. The prevention of rust is of course essential if the cooling system is to be maintained at maximum efficiency. After the cooling system is drained at the end of cold weather, a rust inhibitor should be added to the clear water to prevent the formation of rust.

AIR COOLED ENGINES

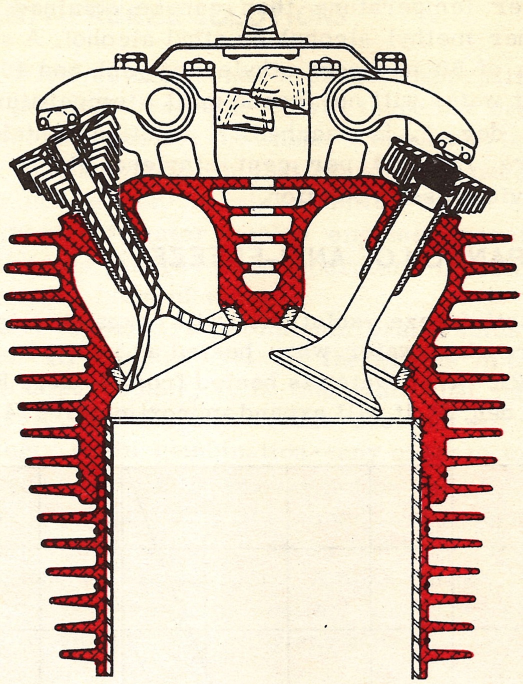
Air cooled engines for automobiles are not new as they were used successfully in the early days of the automobile, but have not been used widely in this country until recently.

Air cooling of a reciprocating piston engine as used in an automobile requires CONSTANT circulation of COPIOUS QUANTITIES of air. This air must be directed where wanted and the volume of air controlled. Forced air circulation is provided by a fan of generous capacity which is usually driven from the engine crankshaft by a belt. See Fig. 11-23. Thus the faster the engine runs, the more air is supplied.

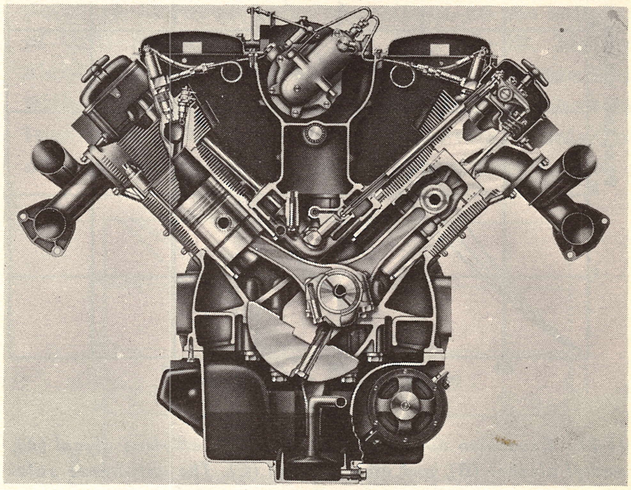
This air must be directed over and through the radiation fins which are a part of, or attached to



11-23. In this case (Corvair) the fan is driven from the crankshaft by a V-belt which makes a right angle turn by running over the generator pulley on one side and an idler pulley on the other side. (Upper section of enclosure here removed).



11-24. Note that the cooling fins on the cylinder head are larger in diameter as well as heavier.

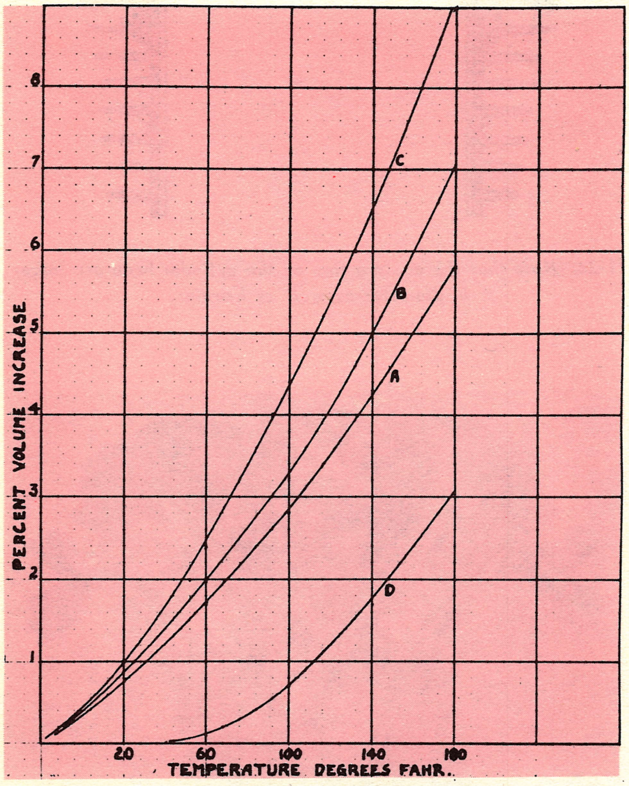


11-25. In this V-type, air cooled Diesel (Deutz) the cooling fins are larger in diameter on the head and have a much greater mass of metal under the fins.

lower temperature than can be obtained with either methyl alcohol or ethyl alcohol. A solution of 60 per cent ethylene glycol and 40 per cent water will not freeze until a temperature of -62 deg. F. is reached. A solution containing more than 60 per cent ethylene glycol will provide less protection.

EXPANSION OF ANTI-FREEZE

Anti-freeze solutions will expand slightly more than water when heated as shown in Fig. 11-21. When water is heated from 40 deg. F. to 180 deg. F. it will expand approximately 1/4 pint per gallon. For the same range of temperature, ethylene glycol will expand 1/3 pint per gallon, methyl alcohol 2/5 pint per gallon, and ethyl alcohol 1/2 pint per gallon. This data is for anti-freeze solutions affording protection to -20 deg. F.

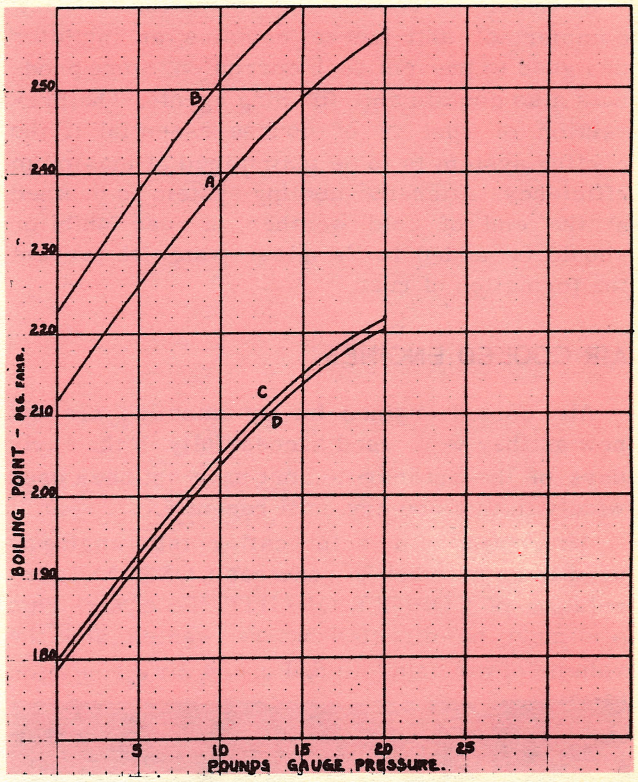


11-21. Expansion due to heat of water (D), ethylene glycol (A), methyl alcohol (B), and ethyl alcohol (C). The anti-freeze solutions giving protection to -20 deg. F.

To avoid loss of anti-freeze due to expansion, the cooling system must not be completely filled. In the case of a 20-quart capacity cooling system completely filled at -20 deg. F., there would be a loss of 2-1/3 pints of ethylene glycol; 2-7/8 pints of methyl alcohol; or 3-2/3 pints of ethyl alcohol when the temperature goes up to 180 deg. F.

BOILING POINT

When ethylene glycol is added to water, the boiling point of the solution is raised. When either methyl alcohol or ethyl alcohol is added to water, the boiling point of the solution is lowered. For example, methyl and ethyl alcohol solutions affording protection to -20 deg. F. will have boiling points of about 180 deg. F. A similar solution of ethylene glycol will have a boiling point of 223 deg. as compared to 212 deg. for clear water. As the pressure is increased, the temperature at which the solution boils is increased as explained previously. Also see Fig. 11-22. Fig. 11-23 shows the effects of altitude on various solutions.

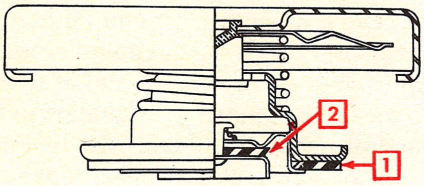


11-22. Effect of pressure on boiling point of various anti-freeze solutions, (A) water, (B) ethylene glycol, (C) ethyl alcohol and (D) methyl alcohol.

EVAPORATION

There is virtually no loss of ethylene glycol solution due to evaporation. Any such loss that does occur is practically all water. In the case of the alcohol types of anti-freeze solution some of the alcohol is lost thus weakening the solution about 180 deg. F., which is below the most efficient operating temperature of the engine. Seven lbs. of added pressure will raise the boiling point of such a mixture to almost 200 deg. F. and thus avoid excessive vaporization, and loss of the anti-freeze solution in most cases.

In order to use a pressurized system, the radiator must be somewhat heavier and stronger, and a special radiator cap must be used. A typical pressure cap is shown in Fig. 11-19. When the pressure caused by the expansion of the water from the heat of operation rises higher than the strength of the spring holding the cap on its seat, the cap lifts like a valve to relieve the excess pressure. Such caps must also have another valve that operates in an opposite manner. This is known as a vacuum valve. When the engine stops and the water cools, a vacuum is created which could cause collapse of the hoses or radiator tank if not relieved.



11-19. A typical pressure radiator cap wherein the pressure valve seal is shown at 1 and the vacuum relief at 2.

Care should be exercised in removing a pressure cap when the engine is running or soon after it stops. The cap should be turned part way to let the steam and hot air escape before the cap is removed entirely. Because of the residual heat, this is particularly true immediately after the engine is stopped. When the engine stops, the cooling also stops and the heat must escape. The temperature of the coolant rises rapidly for a few minutes as may be noted by observation of the temperature gauge.

HOT WATER HEATERS

When hot water heaters are installed on an automobile, they become part of the engine cooling system because they are connected into it. Any rotted hose attached to the heater will need to be replaced when detected. It must be remembered that trash circulating anywhere in the cooling system is liable to get into the small heater core or cores where it will find an ideal place to accumulate until the heater loses its efficiency.

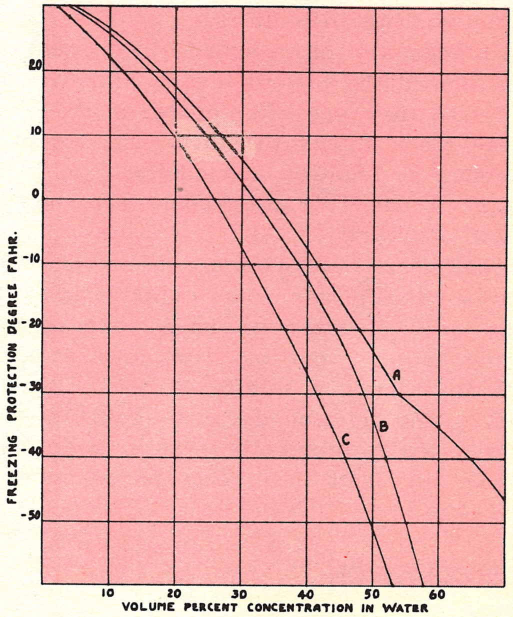
ANTI-FREEZE SOLUTIONS

When water freezes it expands approximately 9 per cent in volume. It will therefore break or seriously distort the shape of the vessel in which it is contained. For that reason it is necessary to use a non-freezing solution in the cooling system of water cooled engines operated in climates where the temperature is below the freezing point of water.

As copper, iron, aluminum, brass, solder, etc. are all used in parts of the engine in contact with the coolant, it is important that the material used for anti-freeze does not corrode--singly or in combination--any of these metals. Also the material should not be harmful to the various types of rubber used in the connecting hoses. Many different materials have been used as anti-freeze solutions. Among the more suitable are: methanol (methyl alcohol), ethanol (ethyl alcohol), and ethylene glycol.

FREEZING PROTECTION

The mixing of an anti-freeze with water forms a solution which has a lower freezing point than the water. The amount the freezing point is lowered is proportional to the amount of anti-freeze added. See Fig. 11-20. Methyl alcohol gives the greatest freezing protection, with ethylene glycol next, and ethyl alcohol the least effective of the three. However, a solution of ethylene glycol protects against freezing to a



11-20. Freezing protection afforded by different concentrations of (A) ethyl alcohol, (B) ethylene glycol, and (C) methyl alcohol.

AERATION OF COOLANT

If the coolant is to serve as a carrier to conduct the heat from the cylinder block to the radiator, it should be free from aeration or bubbles. If the pump seal is scored, the seal spring weak, or any looseness exists in the hose connections on the suction side of the water pump, air may enter even where the water does not leak out. Air in such cases is drawn in when the engine is running faster than at idling speed.

A leaking cylinder head gasket may also permit air to be forced into the cooling system from the compression or explosion pressure in the cylinder. In severe cases, bubbles can be observed in the top tank of the radiator. In the case of slight leaks, special testing devices are helpful in locating the source of the leak.

COOLING FANS

The fan is intended to draw air through the radiator core. It should be a specified distance from the radiator core in order to be effective. The car manufacturer specifies the proper distance in any case where the fan or radiator is so mounted as to be movable.

Bent fan blades are very common but are seldom checked. Bent blades result in inefficiency, noise, vibration and wear on the fan shaft. Fans are carefully balanced because they run at high speed. Worn pulleys, loose and slipping belts, and worn belts are difficult to detect unless they are seriously worn, but are responsible for many cooling difficulties.

Fan blades are often spaced at unequal distances around the hub to lessen vibration and noise. Also they are often curled at the tips to increase their ability to move air. Except for differences in location around the hub, it may be assumed that all blades should have the same pitch and angularity.

As cooling fans absorb a considerable amount of the engine power, particularly at higher speeds, several attempts have been made to have the fan cut out or slow down at higher speeds or when the engine is cold. Electric, hydraulic and friction devices--some of them thermostatically controlled--have been used. One type as used in production is shown in Fig. 11-18.

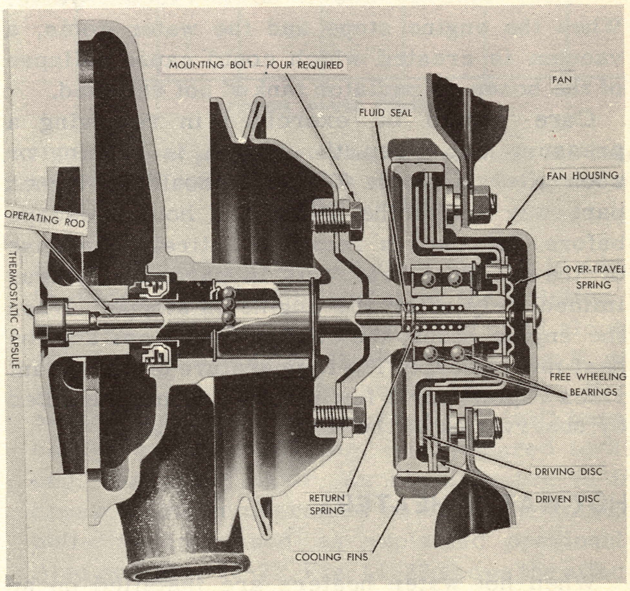
AIR CIRCULATION

As the final dissipation of the heat is from the radiator core to the air, the air must contact the radiator core in sufficient volume. If a license plate or other obstruction is placed in front of the core, the air flow will be restricted. If the air passages are choked with insects, leaves, etc., a free flow of air will not be possible. If the system was designed to include a fan shroud behind the radiator, it should not be removed or deformed as it is intended to direct and control the flow of air.

Ordinary paint is an insulator and if the radiator has been so painted, the paint should be removed with chemical paint remover. The radiator should then be sprayed lightly with special radiator paint.

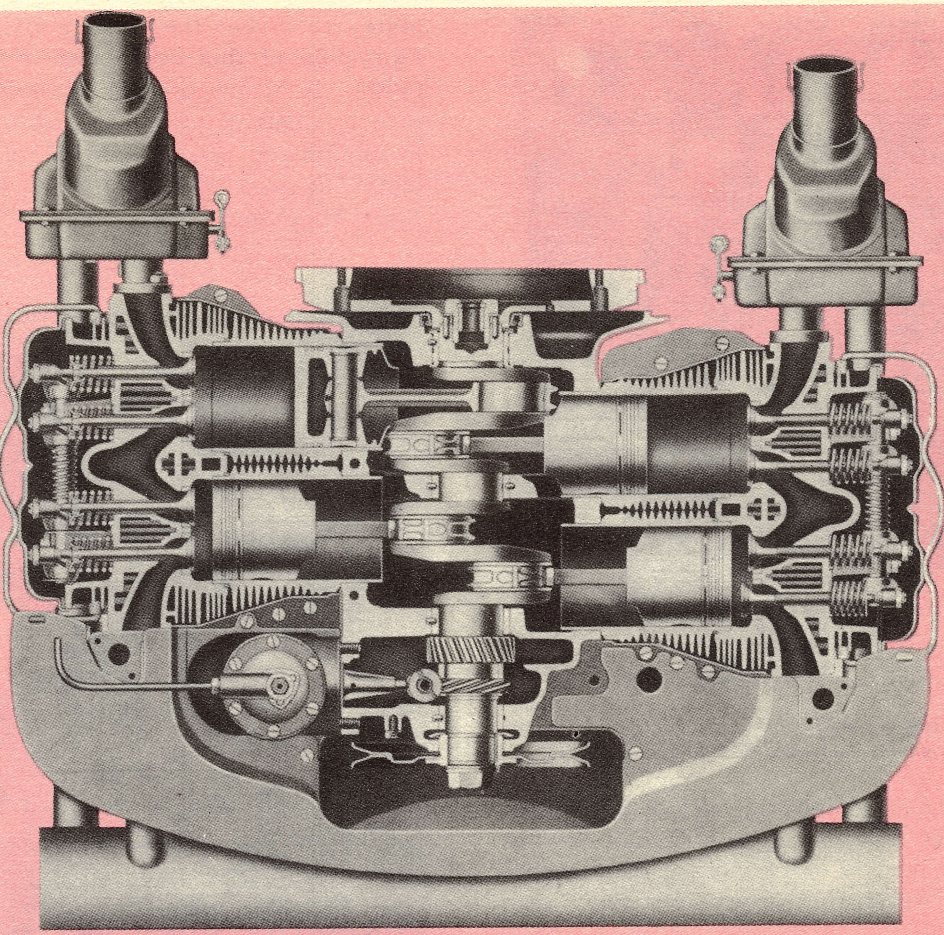
PRESSURE SYSTEMS

As we all know, water boils at 212 deg. F. at sea level. On a mountain 10,000 ft. high, water will boil at 194 deg. F. because of the lower atmospheric pressure. We can raise the boiling point of water by putting it under pressure. Each pound of pressure added will increase the boiling point of water about three degrees. Thus by adding 7 lbs. pressure to the system, the boiling point at 10,000 ft. altitude will be back to 211 deg. F. Or at sea level it will rise to 233 deg. F.

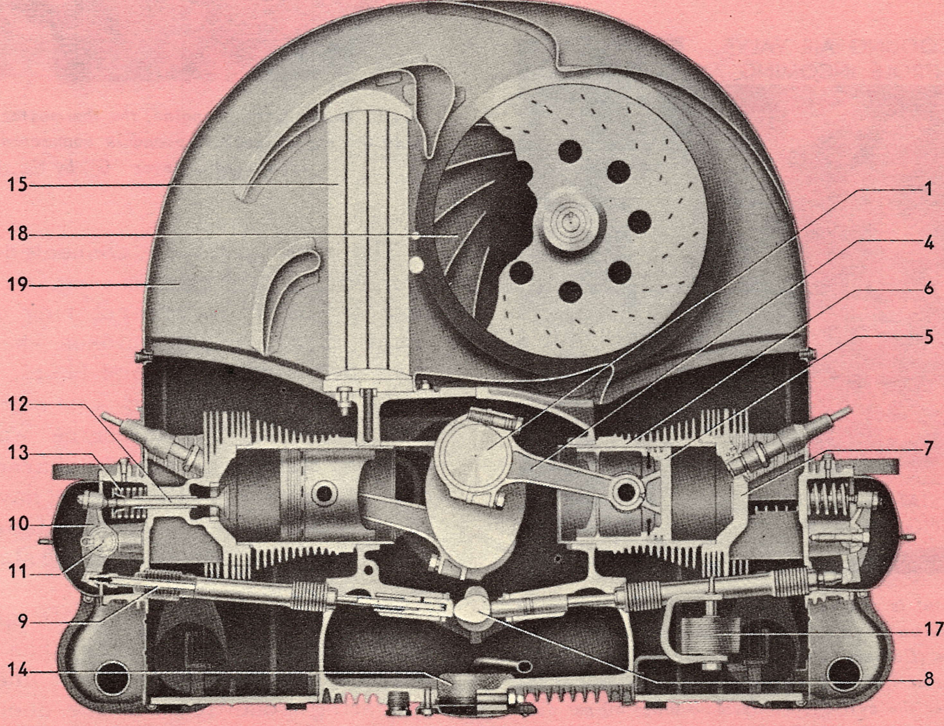


11-18. Controlled type fan as used on Mercury.

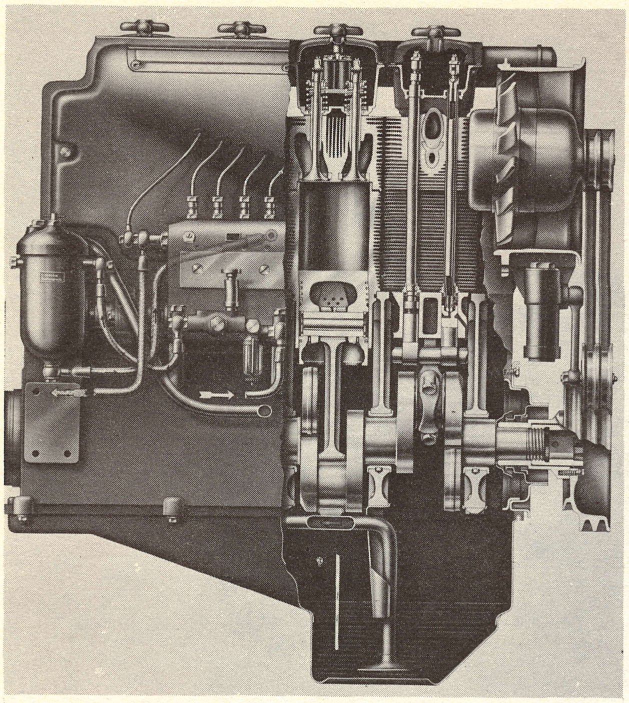
A pressurized cooling system provides a wider margin between the desirable operating temperature, and the boiling point of the water. This is also helpful when the volatile type anti-freeze is used. An alcohol anti-freeze mixture for protection to 20 deg. below zero boils at



11-26. *Instead of solid masses of metal around the valves in this engine (Volkswagen), the metal is finned to increase the radiation surface. Note how closely the sheet metal baffle plates fit the contour of the cooling fins.*



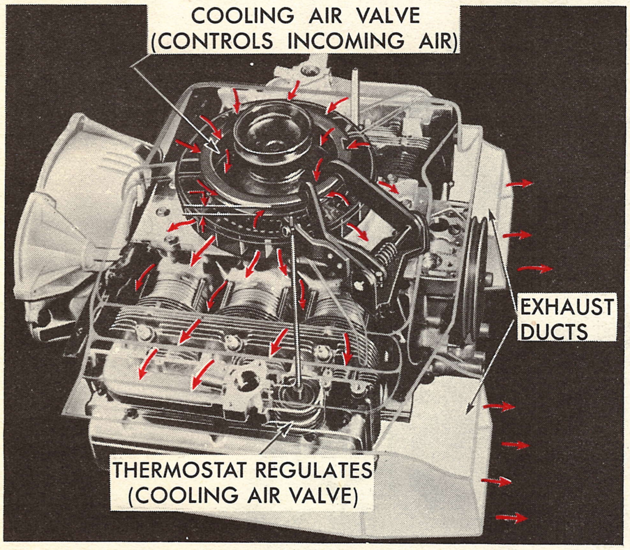
11-27. *The entire Volkswagen cooling system is enclosed by a sheet metal housing. Thermostat at 17, fan at 18.*



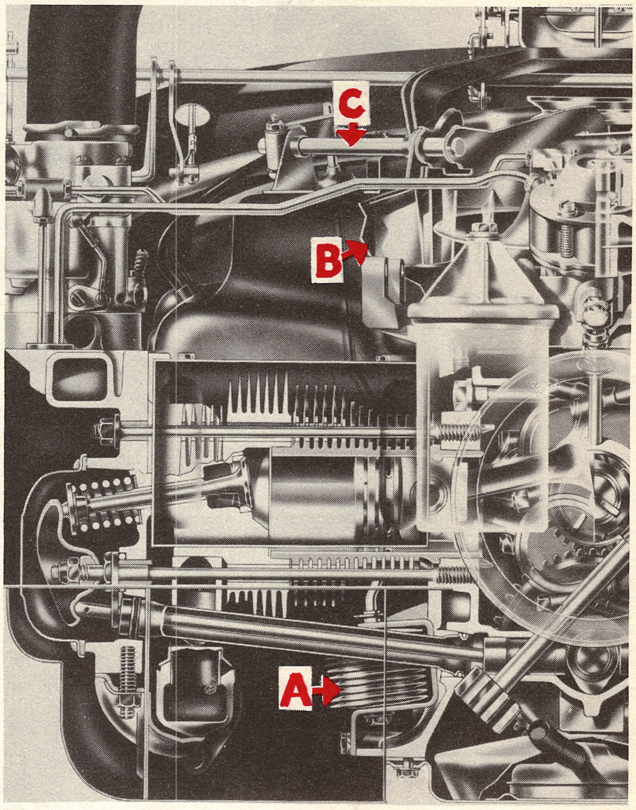
11-28. This air cooled, in-line Diesel (Deutz) has the fan mounted in one end of the engine enclosure. Note fins between valves.

the cylinder head and walls. See Fig. 11-24. These fins have more radiation surface on the head where the heat is more intense than on the lower cylinder walls which run cooler. See Figs. 11-25 and 11-26.

Air cooled engines are, therefore, usually surrounded by a metal housing and suitable baffle plates to direct the cooling air where desired. Examples of this are shown in Figs. 11-27 and 11-28. In order to regulate the engine temperature by controlling the volume of cooling air, it is customary to install a thermostat inside the metal housing which encloses the engine. See Figs. 11-29 and 11-30.



11-29. The thermostat is connected directly to the air valve or damper ring which controls the volume of cooling air entering the system. In this case (Corvair), the fan has a capacity of 1,800 cubic feet per minute at 4,000 r.p.m. and about 60 per cent of the cooling air flows over the cylinder heads. The other 40 per cent is directed over the cylinders.

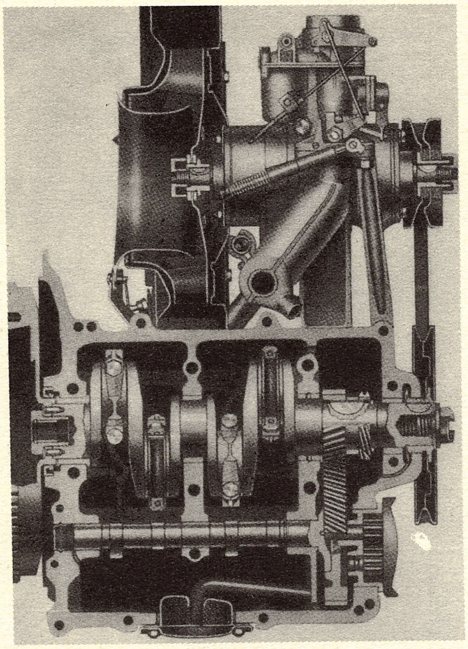


11-30. In the Corvair engine, the thermostat "A" is located inside the engine enclosure and is connected directly to the air valve control lever "C" by the rod "B."

The thermostat is connected directly to a damper, or air control ring. As the engine becomes hotter the control ring opens wider to admit more air, and closes when the engine is cold. See Figs. 11-31 and 11-32.

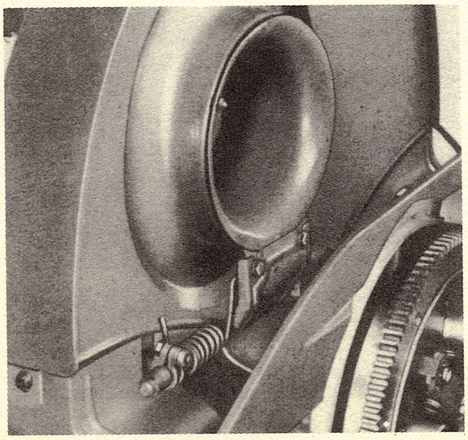
With the ring closed, air circulation is restricted, and a cold engine warms up more rapidly. Rapid warm-up is characteristic of air cooled engines, as they do not have to heat water in cylinder jackets and radiator. This rapid warm-up is helpful in avoiding sludge and crankcase dilution.

Air cooled engines normally operate at somewhat higher temperatures than water cooled engines, but do not overheat under almost any operating conditions if the cooling system is maintained in reasonably good order. If they should overheat, it might be due to improper operation. Air cooled engines should never be "lugged." If the engine is pulling hard at slow speed, more than usual heat is generated in the cylinders at the same time that less cooling air is supplied because of the slower fan speed. In this case there is no reservoir of water to absorb the excess heat, as on a water cooled engine. Therefore the engine speed should be maintained by shifting to a lower gear.



11-31. The air control ring or valve (20) on the Volkswagen is mounted within the fan and moves in and out as required to control the volume of cooling air supplied to the fan.

This higher engine operating temperature is claimed to mean higher engine efficiency, but is also accused of causing noise. One reason given for air cooled engines being noisier than water cooled engines is that there is no silencing provided by water jackets. Another reason given is the somewhat greater clearance sometimes provided between some operating parts. This for the reason that higher temperatures require more room for expansion of the metals.



11-32. Method of controlling Volkswagen air control ring by swinging it in or out on cross shaft.

Regardless of the advantages and disadvantages of air cooling, it has proved to be entirely successful for automobiles, trucks, tractors, airplanes, boats and all kinds of small engines.

QUIZ - COOLING SYSTEMS

1-How much of the heat energy in the fuel must be handled by the cooling system: one fourth ---, one third---, one half---?

2-What happens to the balance of the heat energy?

3-Several thousand gallons of water is circulated through the cooling system every hour of operation. True---, False---.

4-The water jackets dissipate most of the heat from the cylinders to the air. True--- False---.

5-What is rust?

6-Name two causes of engine hot spots.

7-Automobile engine water pumps are usually of the positive displacement type. True---, False---.

8-Why are water pump vanes often curved?

9-A water pump seal may leak: air---, water ---, both---.

10-Thermostats are installed: between the pump inlet and the radiator---, between the pump outlet and the water jacket---, between the water jacket outlet and the radiator---.

11-What is a radiator flow-meter?

12-Name two causes of bubbles in the cooling water.

13-Water boils at a lower temperature at high altitudes. True---, False---.

14-Why is a vacuum valve needed in a radiator pressure cap?

15-When water freezes, it expands approximately: 4%---, 6%---, 9%---.

16-Which protects against freezing to the lowest temperature: ethylene glycol---, methyl alcohol---, ethyl alcohol---?

17-An ethylene glycol solution will boil at a lower temperature than water. True---, False---.

18-In an air cooled engine, how much of the total volume of cooling air is usually directed to the cylinder heads: 40%---, 60%---. 80%---.

19-How can an air cooled engine with the cooling system in good working order become overheated?

20-What can be done to avoid such overheating?

21-Name two possible reasons why an air cooled engine might make more noise than a comparable water cooled engine.

22-What is one distinct advantage of an air cooled engine?

OTHER ENGINES

DIESEL ENGINES

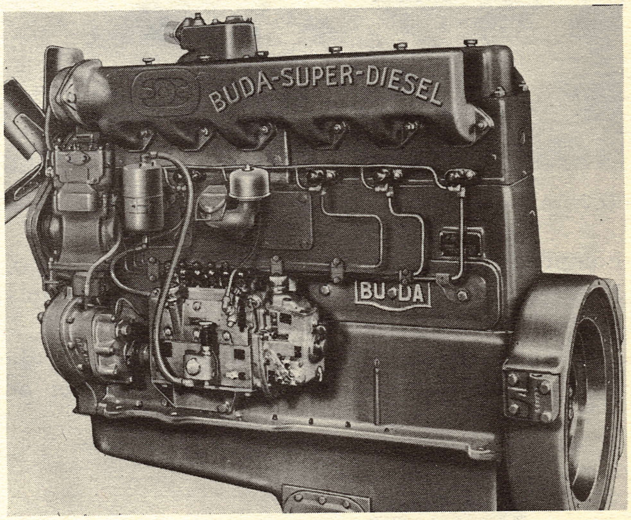
Diesel engines are similar to gasoline engines and are built in both two and four-cycle designs. They may be water cooled or air cooled. In general, they are heavier in structure to withstand the higher pressures resulting from the high compression ratios used. In a full Diesel engine the compression ratio may be as high as 18 to 1. What is known as a "semi-Diesel" engine usually employs a somewhat lower compression ratio and may use spark plugs for ignition.

Previously we have considered the fact that compressing a gas--such as air--generates heat. In the Diesel engine air is compressed so much that it becomes hot enough (1,000--1,200 Deg. F.) to ignite the fuel. The fuel in this case is a petroleum product which is lighter than crude oil, but heavier than gasoline. A gasoline-air mixture cannot be used in a Diesel because it would start to burn from the heat generated by the high compression long before the piston reached the top of the stroke.

The Diesel has no carburetor. The air is compressed in the cylinder and at the proper time the fuel is sprayed into the heated air under pressure. The fuel-air mixture then ignites and burns the same as in a gasoline engine to produce power. Obviously, the entry of the fuel must be "timed" the same as a spark to the spark plug in a gasoline engine. The fuel pumping device is positively connected to the engine crankshaft, being driven by gear or chain. Fig. 12-1 shows fuel pump installed with necessary piping.

FUEL VAPORIZATION

As Diesel fuel is more on the order of oil than gasoline, it does not vaporize as readily. This means that it must be broken up into fine particles and sprayed into the cylinder in the form of mist. This is accomplished by forcing the fuel through a nozzle or a series of very fine holes. Thus as it enters the cylinder, the fuel combines more thoroughly with the air in the cylinder to form a combustible mixture. This is dealt with more fully in the fuel system section of this text.



12-1. A typical four cycle Diesel engine as built by Buda.

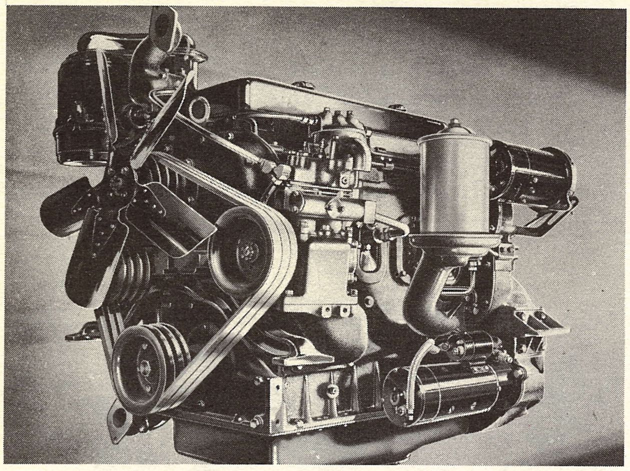
TWO-CYCLE DIESELS

As two-cycle engines are not efficient as air pumps, it is necessary to force air into the cylinder and to force out the burned gas. One means of doing this is to use a supercharger or "blower." The GM two-cycle Diesel, Fig. 12-2, uses a positive displacement type supercharger as shown in Fig. 12-3. There are two exhaust valves, but no inlet valve in each cylinder. The fuel injection nozzle complete with individual pump is located between the two exhaust valves and is operated by a camshaft, push rod and rocker arm.

Air enters the cylinder through holes in the cylinder liner as shown in Fig. 12-3. The blower forces fresh air into the cylinder through these holes during the time the holes are uncovered by the piston at the bottom of the stroke, and at the same time forces the exhaust out through the exhaust valves.

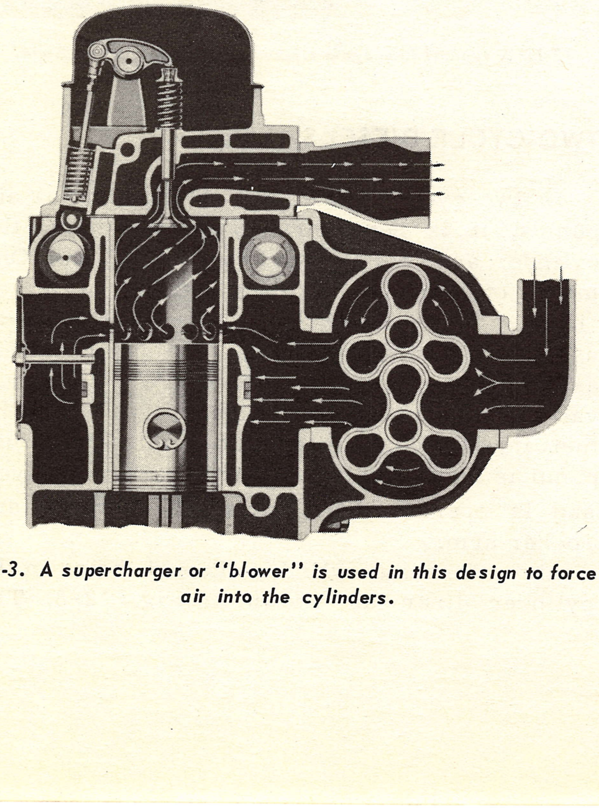
DIESEL OPERATION

As the Diesel engine depends upon the heat of the compressed air to ignite the fuel, the compression pressure must be maintained. Leaking valves or piston rings cannot be tolerated, and must be kept in good condition.



12-2. A two cycle Diesel engine as built by General Motors.

Of equal importance is the proper fuel. While it is possible to build a Diesel engine to run on almost anything that will burn, the automotive type Diesel is designed to operate on a specific type and grade of fuel. Trouble will surely be experienced if an attempt is made to operate on other than the proper type.



12-3. A supercharger or "blower" is used in this design to force air into the cylinders.

MOTOR TRUCK ENGINES

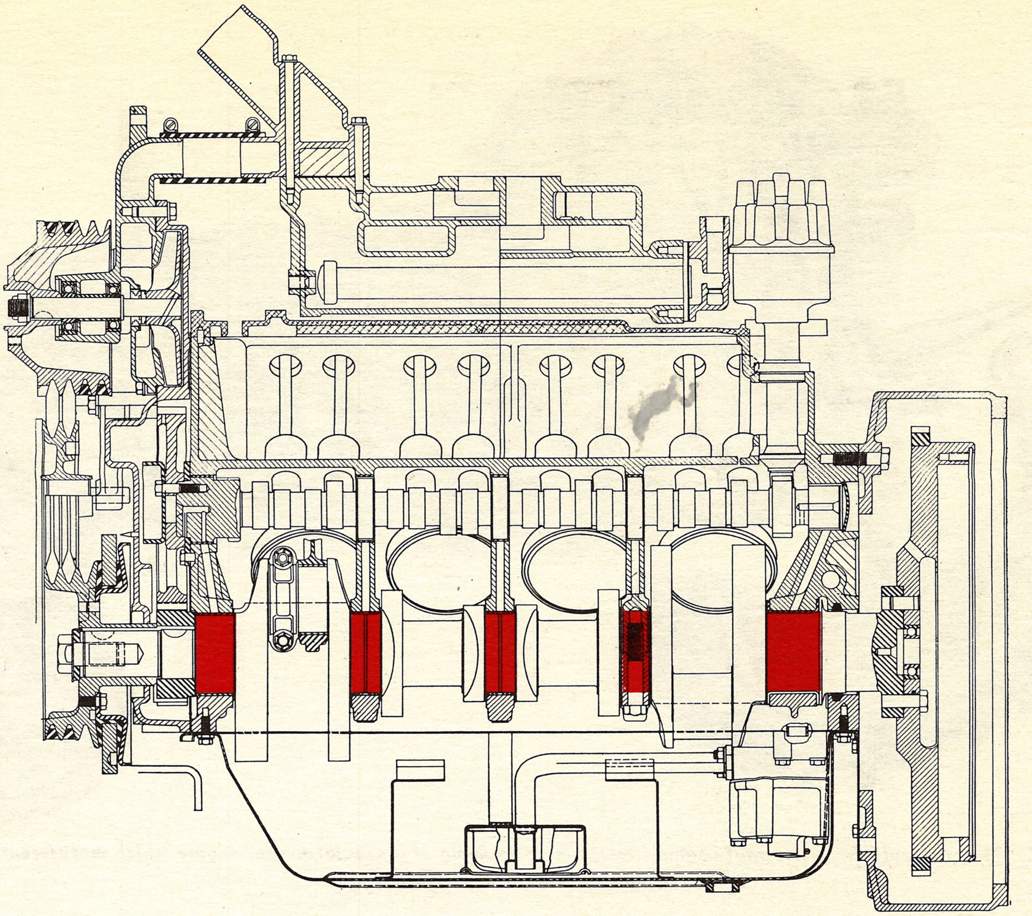
Engines used in light duty trucks are very similar to automobile engines. There are some differences in design and operating conditions, but they are rather minor in nature. Actually, many light trucks use passenger car engines without any change whatever. Heavy duty trucks usually have special engines.

Any changes that are made in a passenger car engine to adapt it to truck use are intended to compensate for the difference in operating conditions. For example, the engine in a truck will be required to move a heavier load, so the axle gearing will be such that the engine can run at higher speed for the same vehicle speed. The result may be that the truck at 60 m.p.h. will have a wide open throttle. Therefore the truck engine will be operating more of the time at full power.

Under these conditions the exhaust valves will run hotter, and may need to be made of heat-resisting steel, and also require special valve seat inserts. The pistons and rings may need slightly greater clearance for heat expansion, etc. The cooling system may require a larger water pump, or a larger radiator or some increase in capacity. A different bearing material may be used on the crankshaft to withstand the higher bearing loads, and an oil pan of larger capacity might be used.

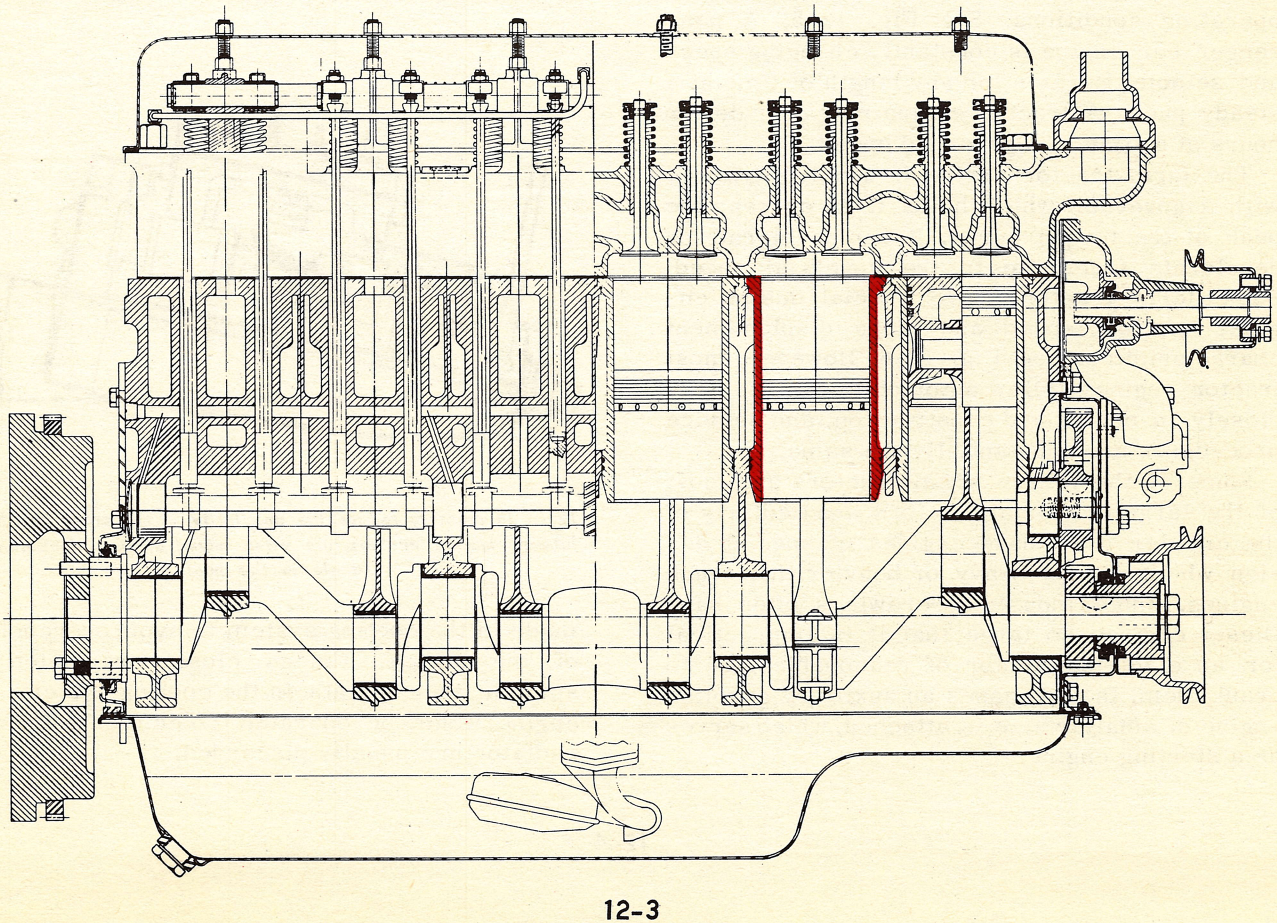
As accelerating ability in a truck is of less importance than in a passenger car, a heavier flywheel may be used in the truck engine. Such changes often serve to adapt the passenger car engine to use in a truck without making any major design changes.

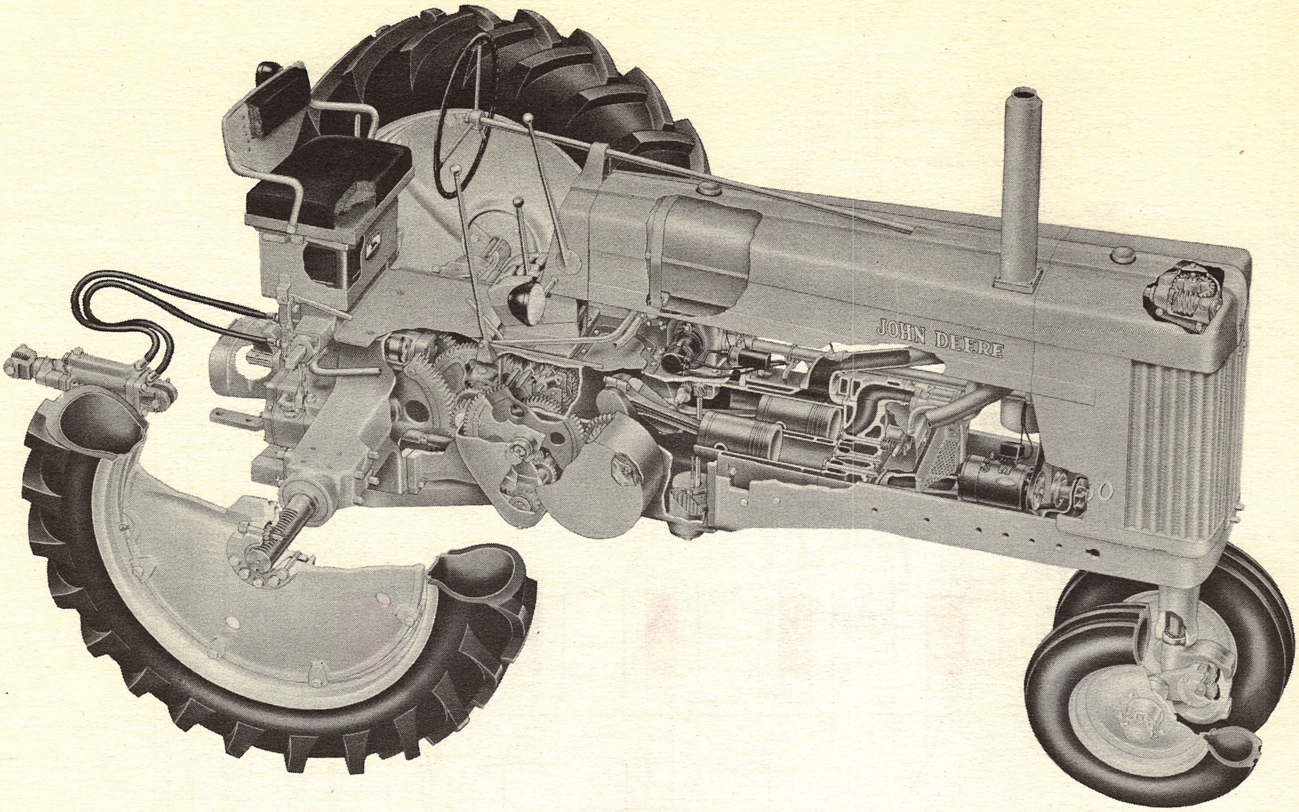
Heavy duty trucks usually have engines that are designed and built for truck use. They may be of either the two or four-cycle type, and may operate on gasoline or Diesel oil. Such engines are customarily much heavier in construction than passenger car engines. Crankshafts are larger in diameter and the bearings are longer. See Fig. 12-4. Crankcases are heavier and braced with webs at points of strain. In general, the piston displacement is increased and the engine speed decreased for a given amount of power.



12-4. *This V-8, overhead valve truck engine (Reo) has a large main bearing in the heavily ribbed crankcase, between each pair of connecting rods. Note depth of crankcase below crankshaft.*

12-5. *This typical tractor engine (Oliver) has individual cylinder sleeves and full length water jackets around each cylinder. Note that crankcase extends below crankshaft bearings.*





12-6. This two cylinder, horizontal engine (Deere) is an example of a special tractor engine which is different from the conventional type of automobile engine.

TRACTOR ENGINES

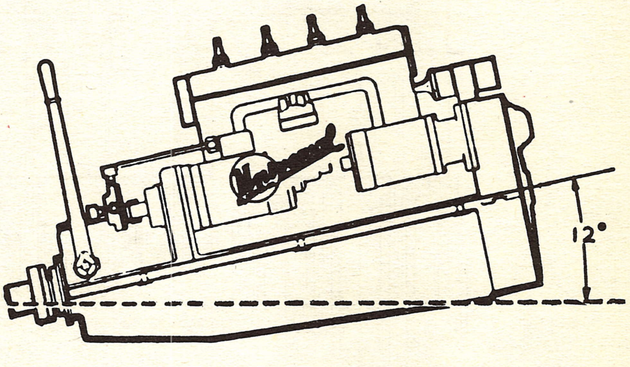
Engines used in farm tractors are usually designed for tractor use, but may be converted from a basic automobile engine design with design changes as needed to better suit tractor operating conditions. See Fig. 12-5. A passenger car engine is constantly changing speed and seldom operates for any length of time at a steady pace. A tractor engine may operate for hours at a time at a governed speed.

The farm tractor engine is usually equipped with a governor which holds it at or near the peak of the torque curve. It can accelerate or decelerate freely up to the governed speed. Some farm tractors have special design engines of low speed and large displacement characteristics. See Fig. 12-6. However, most tractor engines follow automobile engines very closely in design and construction, and service procedures are substantially the same.

Some of the larger wheel tractors and most of the large industrial tractors, particularly of the crawler type, have engines of special design which are as heavy or heavier than truck engines. Huge industrial crawlers often have Diesel engines so large that it is impractical for an electrical motor of reasonable size to crank them. In such cases an auxiliary gasoline engine of smaller size is attached, which serves as a starting engine.

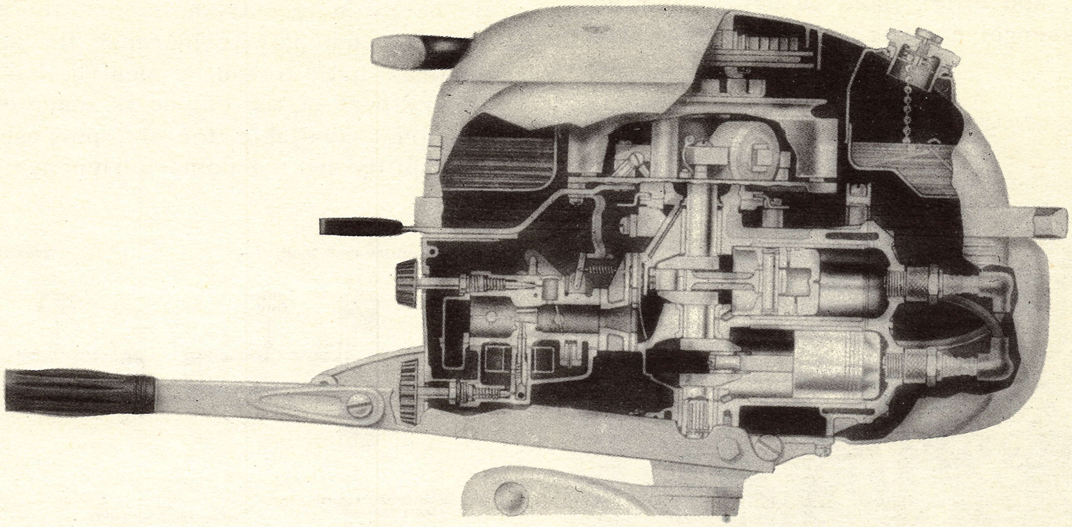
MARINE ENGINES

Automobile engines can be adapted for use in boats but the operating conditions are more like a truck or tractor as boat engines usually run at more constant speed. Changes must be made in the cooling system to avoid overcooling of the engine. Unless closely regulated by suitable thermostats in the cooling system, the engine would be operated too cold. The fan and radiator are usually discarded.



12-7. In order to reduce the angularity of the propeller shaft, inboard marine engines are often mounted at a considerable angle in the boat.

It is also necessary in many cases, to use an oil pan of different shape because the engine is often installed with the rear end much lower than the front to reduce the angularity of the propeller shaft. See Fig. 12-7. It is desirable to equip the engine with a governor to prevent the engine from racing itself to destruction if the propeller shears a pin, or comes out of the water temporarily in rough water.



12-8. This cross section of an Evinrude outboard engine, shows the construction of the carburetor and magneto as well as the engine.

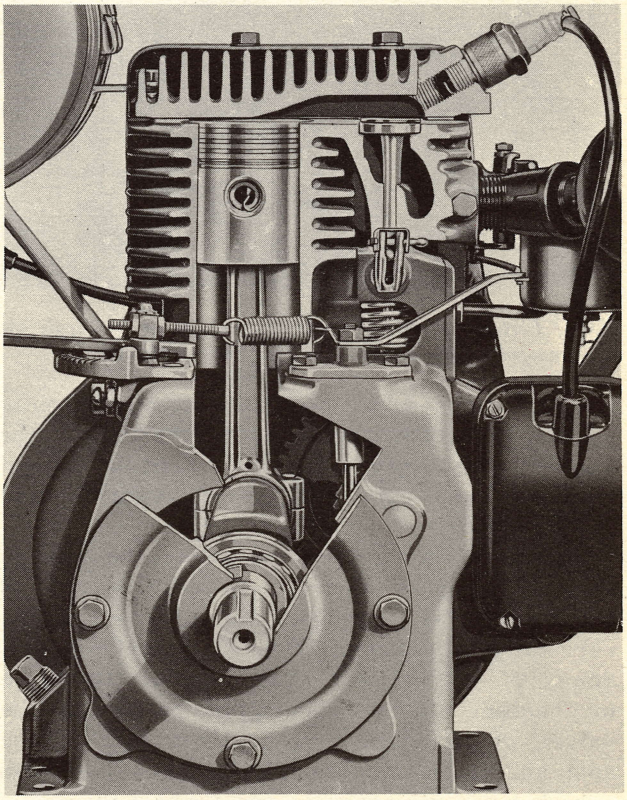
Special marine engines of the inboard type are built quite sturdily to withstand the rigors of constant speed operation. At the other extreme, outboard engines are built as light as possible as they must be portable. They are usually of the two-cycle type. Oil for lubricating the engine parts is mixed with the fuel. See Fig. 12-8.

The bearings in these two-cycle engines are often of the anti-friction type, using steel balls or rollers in hardened races. These engines are available in single and multiple cylinder designs to develop almost any amount of power desired. They are available in air or water cooled types.

SMALL ENGINES

Air cooled engines are used almost exclusively for small machinery such as lawn mowers, chain saws, gardening equipment, etc. Single or multiple-cylinder engines of both two and four-cycle types are entirely satisfactory, and operate for long periods of time with little attention and few repairs. See Figs. 12-9 and 12-10.

Such small industrial engines are usually self-contained power units having built-in fuel and ignition arrangements similar to an outboard engine. The ignition is often supplied by an in-built high tension magneto which is a part of, or attached to the engine flywheel. Thus

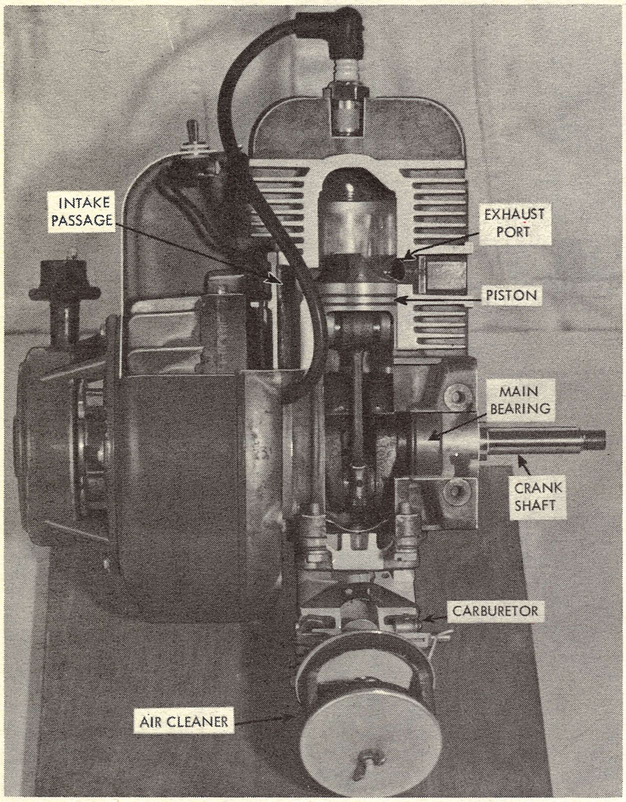


12-9. This partial cut-away shows the construction of a single cylinder, vertical, air cooled, four cycle Wisconsin industrial small engine.

rotation of the engine generates electricity for ignition. These magnetos are described in the electrical section of this text.

RACING ENGINES

The most successful racing engines are designed for the purpose, are made of special materials, and differ from passenger car engines. Passenger car engines can be adapted for racing purposes, but considerable alteration is usually required. When used in a racing car, the engine is designed or altered to get the utmost in power and rotational speed regardless of anything else.

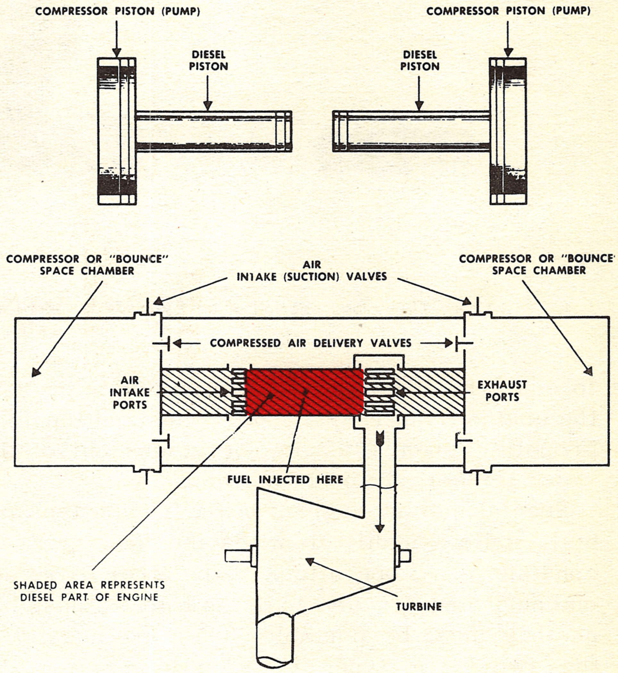

INTAKE PASSAGE
EXHAUST PORT
PISTON
MAIN BEARING
CRANK SHAFT
CARBURETOR
AIR CLEANER

12-10. Partial cut-away showing construction of two cycle air cooled engine as made by West Bend Aluminum Co.

As noise is a minor consideration, the average race car engine sounds like a bucket full of bolts. Actually, however, the clearances are very carefully measured on each working part. Some of this clatter comes from the valve mechanism which is designed to smack the valves open quickly, raise them high off the seat and close them quickly. Large valves with a high lift, will expedite the flow of the gases into and out of the cylinders.

The opening and closing time of the valves, as well as the duration of the valve opening, is designed solely for efficiency at high speed. As a result, racing engines seldom idle smoothly. Other reasons for rough idling are light weight flywheels for rapid acceleration, and the extremely high compression ratios, which approach Diesel practice.

In addition to the greater clearances between all moving parts, each rotating part in the engine is balanced to extremely close tolerance. This is done not only to increase the speed of the engine, but to reduce destructive vibration. Every part of the engine is made of the finest material available for the purpose to insure reliability and freedom from mechanical failure.

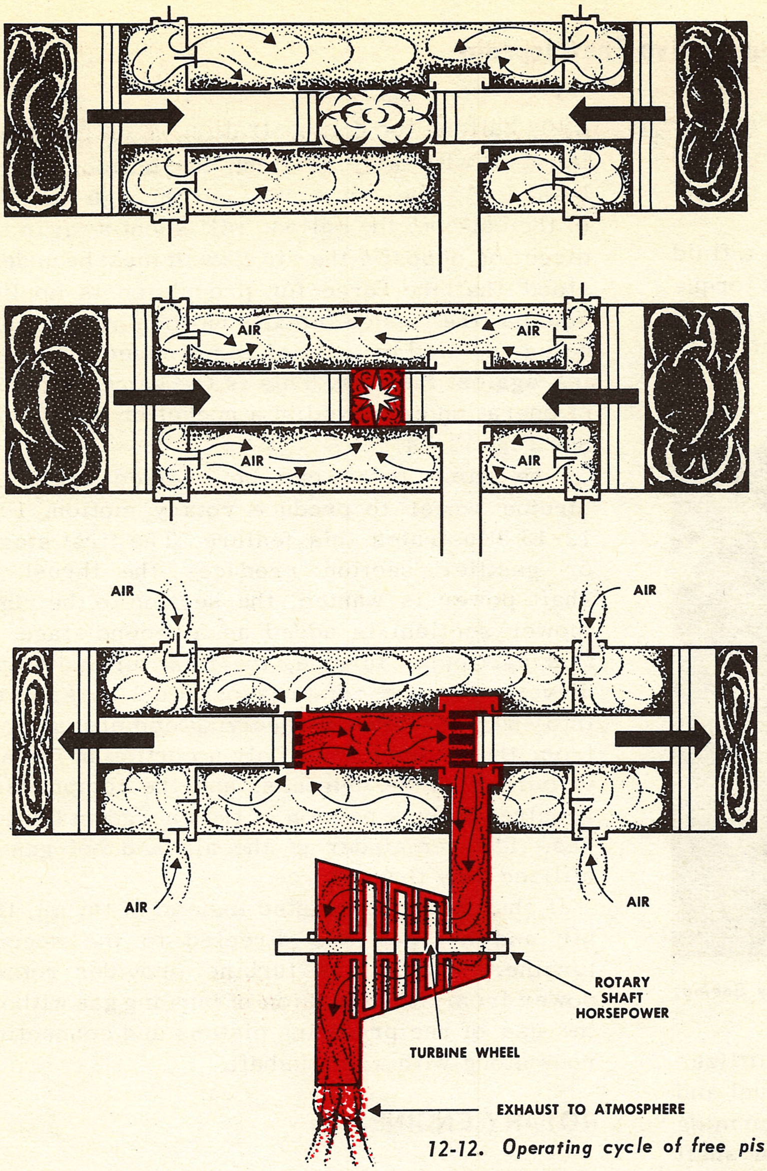

COMPRESSOR PISTON (PUMP)
DIESEL PISTON
DIESEL PISTON
COMPRESSOR PISTON (PUMP)
COMPRESSOR OR "BOUNCE" SPACE CHAMBER
AIR INTAKE (SUCTION) VALVES
COMPRESSOR OR "BOUNCE" SPACE CHAMBER
COMPRESSED AIR DELIVERY VALVES
AIR INTAKE PORTS
EXHAUST PORTS
FUEL INJECTED HERE
SHADED AREA REPRESENTS DIESEL PART OF ENGINE
TURBINE

12-11. Diagram of free piston type of cylinder and dual pistons with the combustion chamber area in color.

AIRPLANE ENGINES

Liquid cooled engines have been used in airplanes, but the air cooled engine dominates the field. Cylinders are arranged in several ways: in-line, pancake, V and radial style. If radial, they may have more than one circle of cylinders around the crankcase. Turbines and jet engines are also used, particularly in military and commercial aircraft.

Aircraft engines of the reciprocating type are made with the utmost precision but the fit of the working parts seems rather sloppy when compared with water cooled engines. This excessive clearance is necessary to provide for the great expansion which occurs in operation. Airplane



Pistons travel inward pumping air from the compressor cylinder into the air box, trapping air in Diesel combustion space. Intake and exhaust ports are closed-air delivery valves are open.

Pistons are completing inward travel. Fuel is injected into cylinder. This is combustion or the beginning of the power stroke. Intake and exhaust ports are still closed—air delivery valves are open.

End of power stroke compressing air in bounce space to return pistons for next cycle. Exhaust and intake ports are just opening to scavenge Diesel cylinder. Exhaust gases escape to turbine, spinning turbine wheels for usable power. Air is being drawn into compressor cylinder.

12-12. Operating cycle of free piston engine.

engines operate at or near full power almost all of the time. The engine is wide open at take-off, and not too far from wide open at so-called cruising speed. Such operation for hours at a time is indeed severe.

FREE PISTON ENGINES

Free piston engines are closely related to both the Diesel and turbine types of power plants, as they use the Diesel cycle along with a turbine which is an essential part of the power plant. See Fig. 12-11.

The engine consists of large and small cylinders, each containing a set of two (one large and one small) horizontally opposed pistons. Several of these pairs of cylinders may be assembled into one power plant and coupled to one turbine. An air-fuel mixture is fired between the opposed small pistons--with injectors as in a Diesel--which drives the pistons apart, compressing air in the closed chambers at ends of the large pistons.

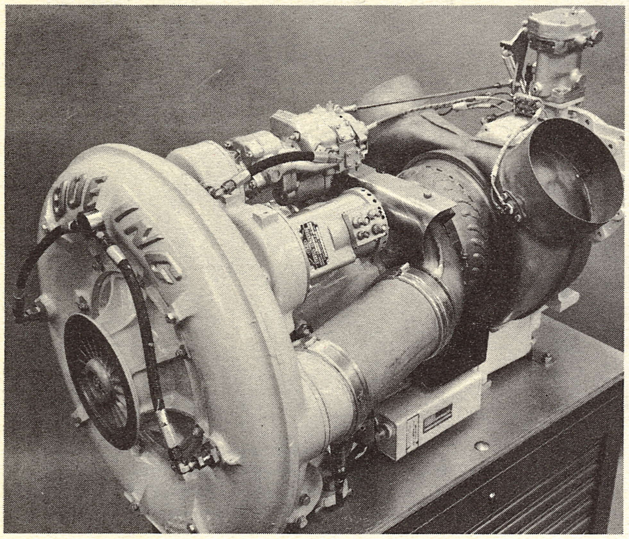
Air thus compressed in the large cylinders then bounces the pistons back toward inner center compressing the mixture in the small cylinders for the next firing stroke. It will be apparent that the compression ratio and piston stroke will vary with the speed of the engine. As the pistons travel inward, the large pistons also compress air and pump it into the Diesel cylinder through the ports uncovered by the small pistons. The cycle of operation is shown in Fig. 12-12.

The expanding hot gas thus generated, goes to the turbine part of the engine to make the power usable. As there are no connecting rods or crankshaft, the pistons are kept in phase with the aid of connecting linkage.

TURBINES AND JETS

Gas turbines are used to propel automobiles, trucks, boats, airplanes and as stationary power plants. See Fig. 12-13. The fundamental principle of a turbine consists of an inclined plane mounted on a rotating shaft, and located in the path of fluid force.

An actual turbine operating with oil as a fluid is found in automatic transmissions of the torque converter type. Several of these are described and illustrated in the transmission section of this text.



12-13. Complete gas turbine engine as manufactured by Boeing.

A gas turbine is a heat engine which utilizes the expansion from the combustion of fuel and air in a combustion chamber, by transforming that energy directly into either thrust or shaft power. This thrust power can be utilized directly to push an airplane or vehicle, or it can be turned into shaft power to turn an airplane propeller, or an automobile wheel.

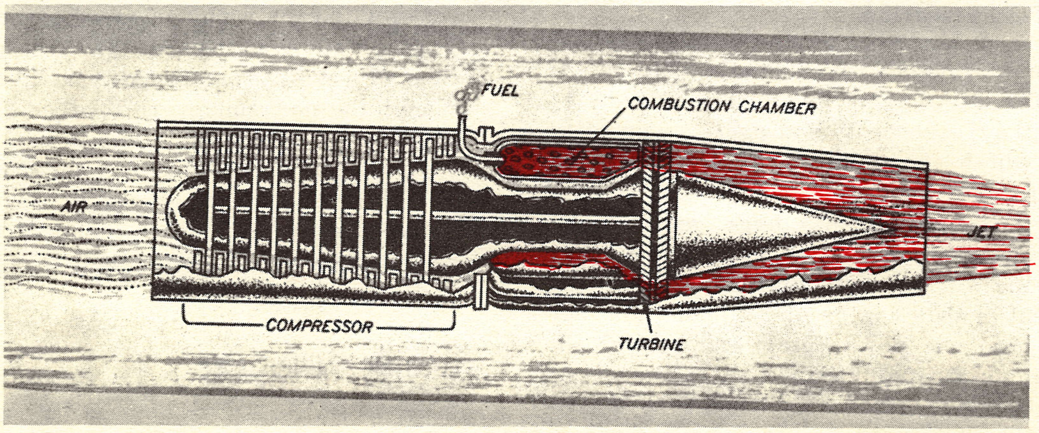
This thrust force may be understood by using a toy balloon for demonstration. A toy balloon is inflated with air, and then the balloon is released. As the air rushes out through the neck of the balloon, the balloon will shoot away in the direction opposite the air flow. It must be understood that the force for propulsion is applied against the inside of the balloon rather than being supplied by a jet of compressed air pushing against free air. This is the same principle of operation employed in a rocket or jet engine. See Fig. 12-14.

The same force can be exerted against a turbine wheel to produce rotary motion. Fig. 12-15 illustrates this feature. The first stage, or gasifier section produces the thrust. If shaft power is wanted, the section to the right (power section) is added as a second stage. In this particular turbine, the first turbine wheel drives only the compressor. Fuel is sprayed into the two burners receiving compressed air from the compressor. Only a portion of the air is burned in the burners, and the compressor requires only a portion of the energy in the hot gas. The remainder of the air and hot gas is utilized as a thrust force.

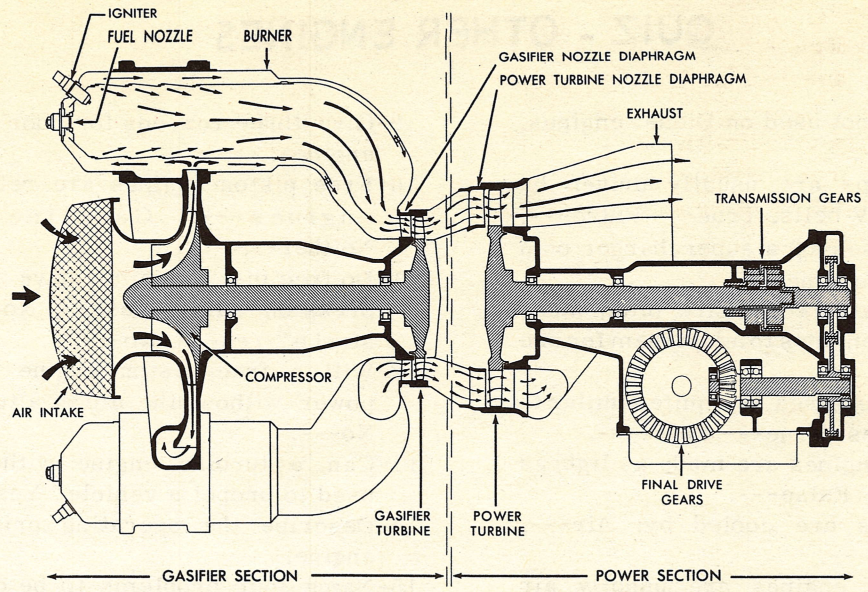
If shaft power is wanted instead of thrust, the air and hot gas are directed to the second turbine. Thus a gas turbine provides rotary power from the expansion of burning gas without the use of reciprocating pistons and connecting rods along with a crankshaft.

ROTARY ENGINES

It will be apparent to the student from the foregoing text that the reciprocating piston engine has certain basic faults. It has been developed and refined to a high degree of efficiency because nothing better was in sight.



12-14. Diagram of jet engine construction.

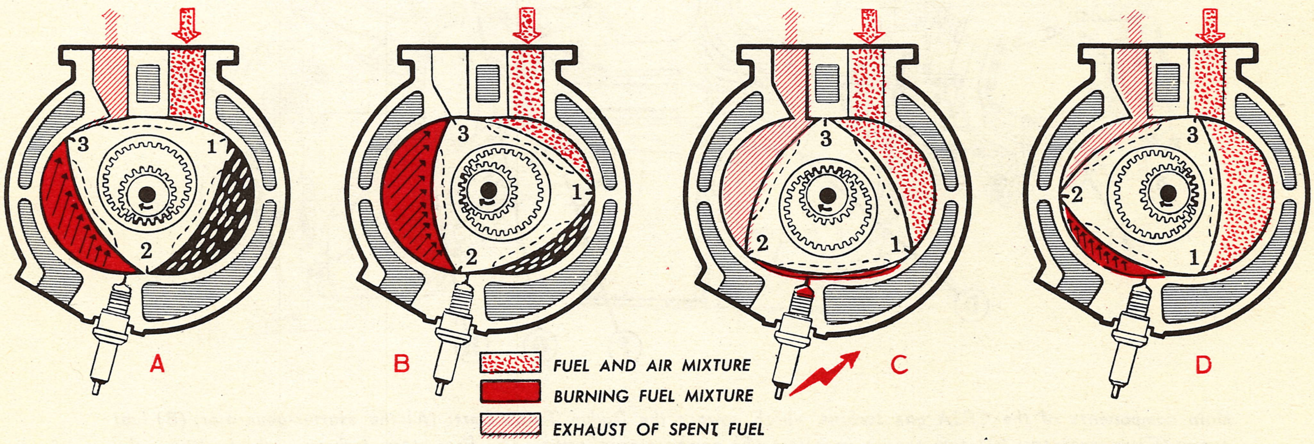

IGNITER
FUEL NOZZLE
BURNER
GASIFIER NOZZLE DIAPHRAGM
POWER TURBINE NOZZLE DIAPHRAGM
EXHAUST
TRANSMISSION GEARS
COMPRESSOR
AIR INTAKE
FINAL DRIVE GEARS
GASIFIER TURBINE
POWER TURBINE
GASIFIER SECTION
POWER SECTION

12-15. GM turbine arrangement as used to propel a vehicle.

Elimination of crankshaft, connecting rods, pistons, poppet valves has long been sought. Many engines have been built that eliminated one or more of the items. Cams have been used to eliminate the crankshaft in some engines. The free piston engine also eliminates crankshaft and connecting rods. Two-cycle engines use the piston to eliminate some or all of the poppet valves.

While the turbine might be considered one type of rotary engine, most attempts to design a rotary engine with no reciprocating parts have presented more problems than they have solved. The principal problems have had to do with operating efficiency, noise, sealing, cooling, lubrication, etc.

One of the more successful rotary engines is shown in Fig. 12-16. In this design, the triangular rotor "floats" inside an oval chamber and is geared to the power output shaft. The cycle of operation includes the familiar phases of intake, compression, power and exhaust as in a piston engine.


A
B
C
D
1
2
3
FUEL AND AIR MIXTURE
BURNING FUEL MIXTURE
EXHAUST OF SPENT FUEL

12-16. (A) Intake is starting between 1 and 3; compression is occuring between 1 and 2; power is being produced between 2 and 3; exhaust is finishing between 3 and 1. (B) Intake continues between 1 and 3; compression continues between 1 and 2; power is finishing between 2 and 3. (C) Intake is finishing between 1 and 3; spark is occuring between 1 and 2; exhaust is occuring between 2 and 3. (D) Intake is finished between 1 and 3; power is being produced between 1 and 2; exhaust is continuing between 2 and 3.

QUIZ - OTHER ENGINES

1-Carburetors are not used on Diesel engines. True--- False---.

2-Diesel fuel pumps are usually driven by double or triple V belts. True--- False---.

3-Name two purposes of a supercharger on a two-cycle Diesel engine.

4-Name five alterations that are often made to passenger car engines to adapt them for use in light trucks.

5-All farm tractor engines are quite similar to automobile engines. True--- False---.

6-Inboard marine engines are made as light as possible. True--- False---.

7-Outboard engines are cooled by: Air---, Water---, Either---.

8-Small industrial engines are usually air cooled. True--- False---.

9-Give three reasons for poor idling of racing engines.

10-Free piston engines are related to: Diesel engines---, Gasoline engines---, Neither---.

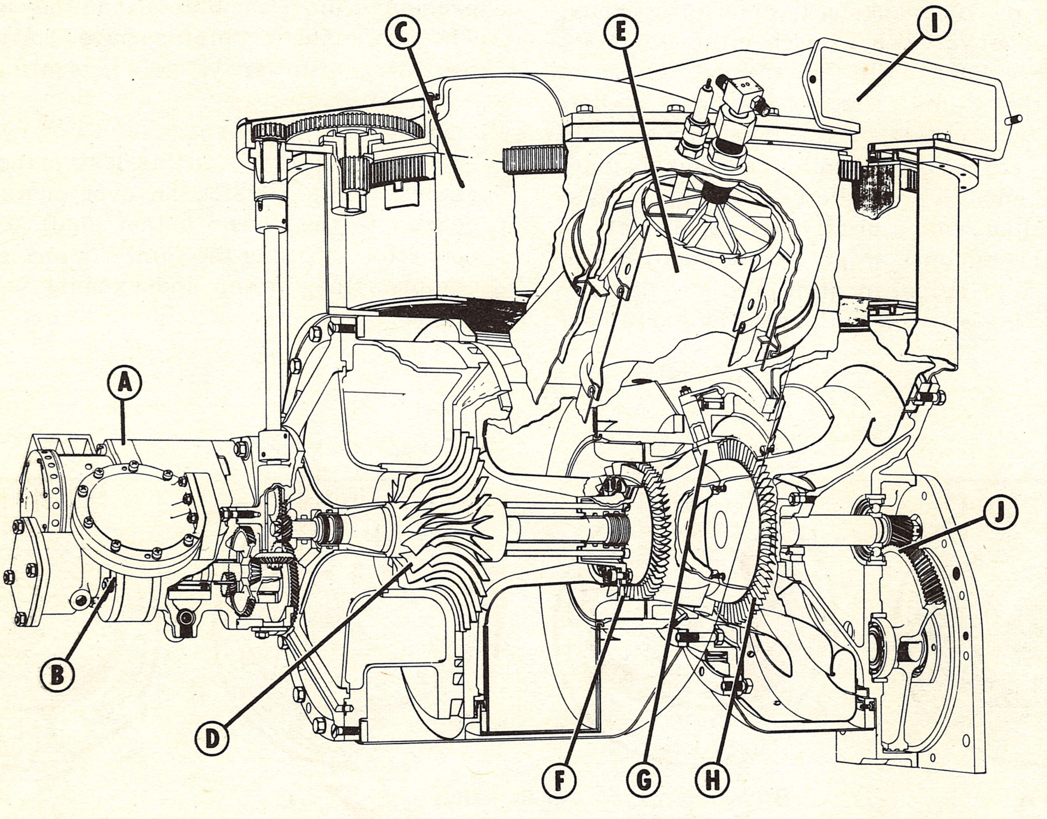
11-Do free piston engines have a variable compression ratio? Yes---, No---; a variable stroke? Yes---, No---.

12-Will a free piston engine produce useful power without the aid of a turbine? Yes---, No---.

13-Can a turbine engine without gearing be used to propel a vehicle? Yes---, No---.

14-Describe the operating principle of a jet engine.

15-Name four problems to be overcome in the design of a successful rotary engine.



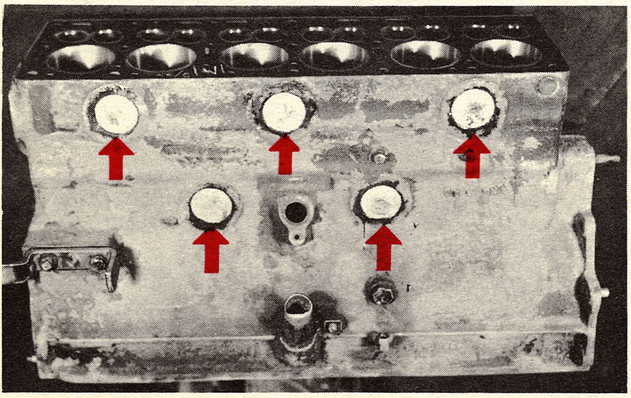
Main components of the CR2A gas turbine which powers the Dodge Turbo Dart: (A) the starter-generator; (B) fuel pump; (C) regenerator; (D) compressor impeller; (E) combustion chamber; (F) first-stage turbine, which drives the compressor impeller and accessories; (G) variable second-stage nozzle; (H) second-stage turbine which supplies power to the driveshaft; (I) one of two exhaust outlets; (J) single stage helical reduction gear of 8.53-to1 ratio which reduces power turbine rpm of 39,000 to 45,730, to a rated output speed of 4,570 to 5,360 rpm.

ENGINE RECONDITIONING

The starting point for engine reconditioning is the cylinder block because practically all other parts are fitted to it. If the block is damaged in any way, it must be repairable or else it must be replaced. There are many things to be inspected and checked.

The first step is dismantling and THOROUGH cleaning. If it is not cleaned down to the bare metal, inspection and accurate measurement will not be possible as measurements must be made in thousandths and fractions of thousandths of an inch. Obviously, the inspector must know how to use precision measuring tools and use them with care.

The engine block or head may be cracked, warped, worn or otherwise damaged. The damage may affect the operation of the crankshaft, pistons, rings, bearings, camshaft, cooling, lubrication, etc. The extent of the damage will determine whether or not the block is repairable. There are many methods of changing the condition or dimensions of metal parts. Several different methods may be used to restore an engine to good condition.



13-1. Leaking plugs are punched or cut out, and new expanding plugs installed.

METAL PARTS RESTORATION

If we wish to reduce the size of a part, we can cut or grind or etch the metal away or in some cases we can shrink it with freezing, or pressure.

If we wish to increase the size of a part, we can add metal by soldering, brazing, welding, plating or spraying. In some cases we can expand it by heat and pressure.

Thus in many cases we can compensate for wear by expanding or shrinking the metal. Or we can add metal to the worn surface to restore it to usefulness. In adding metal we have a wide choice of materials each of which possesses certain characteristics which may be desired for the particular purpose.

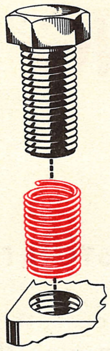
If we want a soft surface, we can use tin or bronze. If we want a hard surface we can add steel of any desired degree of hardness by welding. Another method of adding a hard surface is by the electroplating process. An example of this is a chrome surface on a piston ring.

In engine repair work, we often add material to, or increase the size of, one part without disturbing the mating part. An example of this is to spray molten metal on a worn crankshaft journal to avoid installation of undersize bearings. Or, we may expand a piston with heat or pressure or both, and reinstall it in the mating cylinder.

In other cases we remove metal from one part, and install an oversize or undersize mating part, in order to obtain the proper clearance. Examples of this are rebored cylinders and oversize pistons or a reground crankshaft and an undersize bearing.

In still other cases we may remove metal for the sole purpose of obtaining a better surface fit of two mating parts. An example of this is the correction of a warped cylinder head, by surface grinding to restore a flat and true surface.

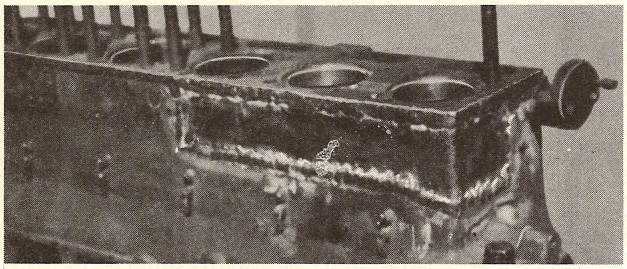
For practically all of these operations special tools and equipment are available. These tools will do a satisfactory job if they are properly handled. Obviously, it will be essential to measure accurately, adjust carefully and operate in accordance with the manufacturers' instructions.



13-2. *Special Helicoil thread insert restores damaged threads in holes.*

CRACKED CYLINDER BLOCKS

After the cylinder block and head are completely cleaned, a visual inspection is made for cracks or serious damage. Included in this inspection is the condition of the core hole or water freeze plugs. See Fig. 13-1. If signs of leakage or corrosion are found the plugs should be replaced. Threads on studs and in stud holes are checked, and new studs installed if needed. If a stud hole in the casting has worn or damaged threads, they can be repaired by means of special inserts as shown in Fig. 13-2. This thread check is particularly important in the case of aluminum blocks, or heads, as careless tightening often overstresses the metal and the threads are deformed or stripped.



13-3. *Typical repair to bursted water jacket*

If the block was cracked by water freezing in the water jacket, the crack can usually be closed satisfactorily by a process known as copper-welding or by brazing. It can also be welded shut with iron. See Fig. 13-3. In the case of welding with iron, it is difficult to prevent warping of the block unless the block is preheated and the welding expertly done.

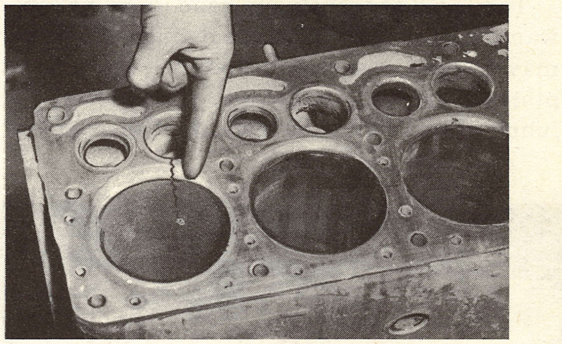
In cases where a panel or section of the water jacket is broken out, it is sometimes possible to shape a metal plate into a patch corresponding to and slightly larger than the opening. The patch is then attached to the block by means of multiple screws around the edge of the patch. Holes are drilled and tapped in the block for the screws.

In the case of small cracks--depending upon the location--iron cement can be used for a quick repair. If the crack is in a thin, large section which is readily accessible, it may be possible to tin the cast iron and solder the crack. It is very difficult to solder aluminum.

The choice of the repair method will depend upon the size of the damaged area, the location of the crack, the cost of a new block as well as the value of the automobile.

INTERNAL CRACKS

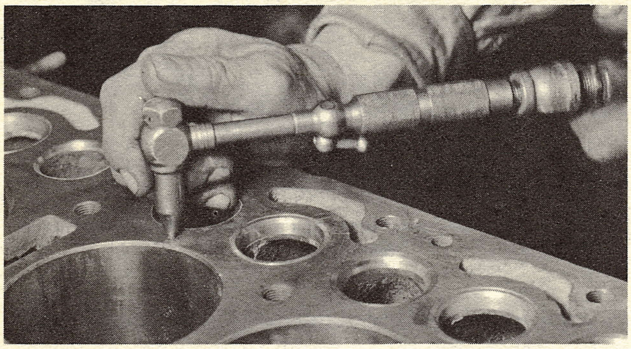
At times, the cylinder wall will crack through to the valve port as shown in Fig. 13-4. Or the crack may be in the cylinder head of overhead valve engines. Such cylinder heads are often replaced rather than attempt repair. If the crack is between the cylinder wall and the valve seat, the repair will need to be made with extra care. One method is welding. If the crack is small it may be possible to peen it shut with a power peening hammer. See Fig. 13-5.



13-4. *A cracked valve seat may extend into the cylinder bore or water jacket of block or head.*

Still another method consists of drilling holes at the ends of the crack, threading the holes and inserting threaded plugs or screws. Another hole is then drilled partly in the block and partly in the plug or screw. A second plug or screw is then inserted and this process continued to the other end of the crack.

After the screws are all installed and the crack thus sealed, the surface is then machined smooth and the cylinder bore and valve seat are resurfaced. If the valve seat is badly damaged, the block can be counterbored and a new valve seat inserted. Sometimes these seats are screwed into place and in other cases, they are pressed in place and the edge of the metal block peened over slightly to hold them in place.



13-5. Cylinder blocks may crack between the valve port and the cylinder wall. If not too serious, these cracks may be closed with a peening hammer as shown here. In more serious cases, welding or plugging may need to be employed.

In either case, they must fit tightly so that metal-to-metal contact will be intimate enough to offer a full and free flow of heat from the insert to the block and cooling water. The same is true in the case of serious cylinder damage where the repair consists of reboring the cylinder and inserting a sleeve. The contact between sleeve and cylinder must be full and complete.

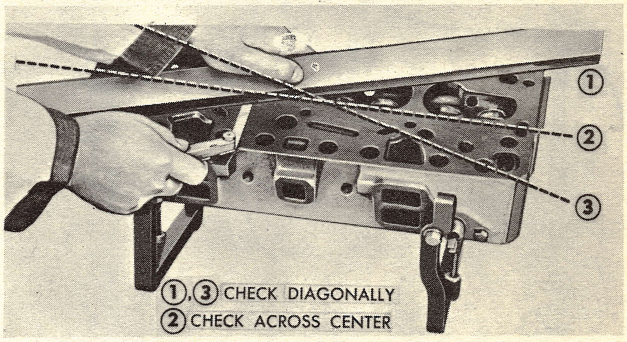
In repairs of this nature, it must be kept in mind that the heat and pressure in the cylinder will cause expansion, contraction and possibly warpage of the cylinder wall, valve seat and cylinder block surface as soon as the engine is operated. Therefore the work must be done as carefully and accurately as possible, and no great amount of excess metal added at any point to aggravate distortion.

CORROSION

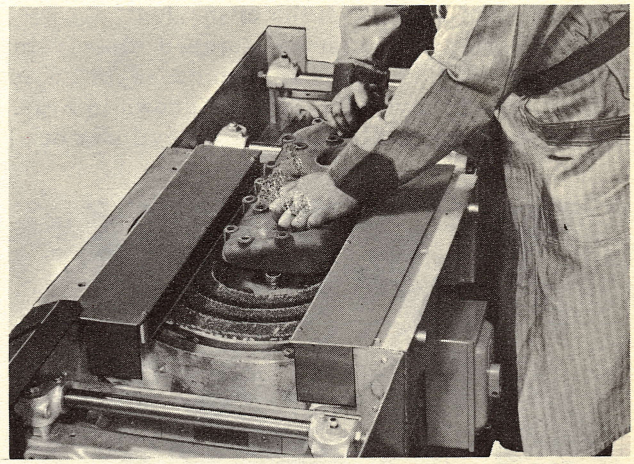
In the case of aluminum engine blocks or heads, the visual inspection should be particularly thorough to detect any possible corrosion of the metal. Sometimes corrosion of the metal around the water circulation openings will occur from chemicals in the cooling water--particularly in localities where the water supply contains more than the usual amount of chloride. Corrosion from electrolytic action may also occur, because of the dissimilar metals found in the engine cooling system. If corrosion is serious enough, it may interfere with the seal of the gasket between head and block, and permit coolant to enter the combustion chamber, or compression pressure to escape to the water jacket.

CYLINDER HEAD WARPAGE

It is not at all unusual to find cylinder heads warped, and sometimes the cylinder block mating surface will be warped. These mating surfaces should be flat and true within .020 in. Measurement is made by means of a steel straight edge and feeler gauge strips as shown in Fig. 13-6. If the surfaces are warped or damaged, they can be ground flat and true on special equipment made for the purpose. See Fig. 13-7.



13-6. The cylinder block head surface may be checked for distortion in the same manner.

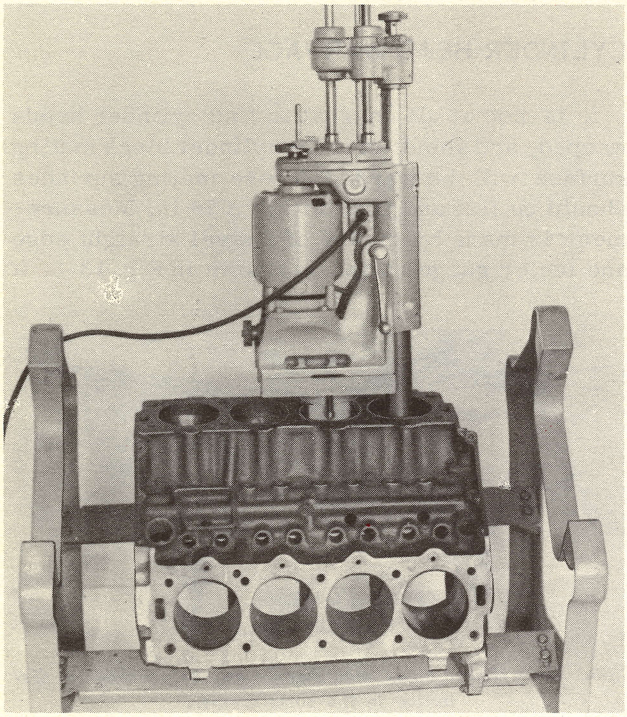


13-7. One type of grinding machine for resurfacing cylinder heads or blocks.

CYLINDER RECONDITIONING

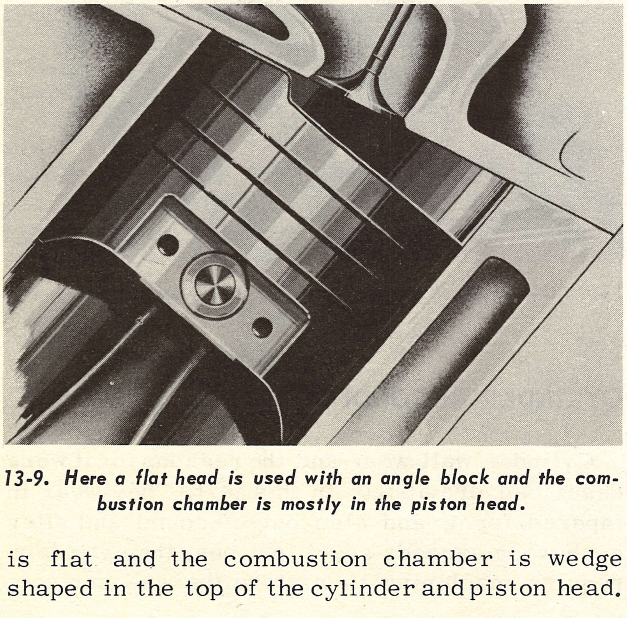
Cylinder wall wear and the reasons for it were described previously in this text. They wear in tapered form, and also out-of-round and after such wear exceeds specifications, the cylinders require machining to restore the wall surface.

A wide variety of equipment is available for this purpose. See Fig. 13-8. In any case it is essential for the reconditioned cylinders to be absolutely parallel with one another, and at precise right angle with the crankshaft.

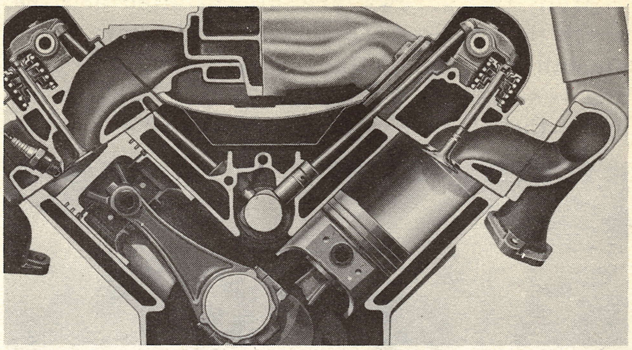


13-8. Cylinder bore reconditioning equipment mounted on V-8 block.

This angularity must be watched closely in cases where the cylinder head face is at an angle with the cylinder bore as shown in Figs. 13-9 and 13-10. In these cases the cylinder head is flat and the combustion chamber is wedge shaped in the top of the cylinder and piston head.

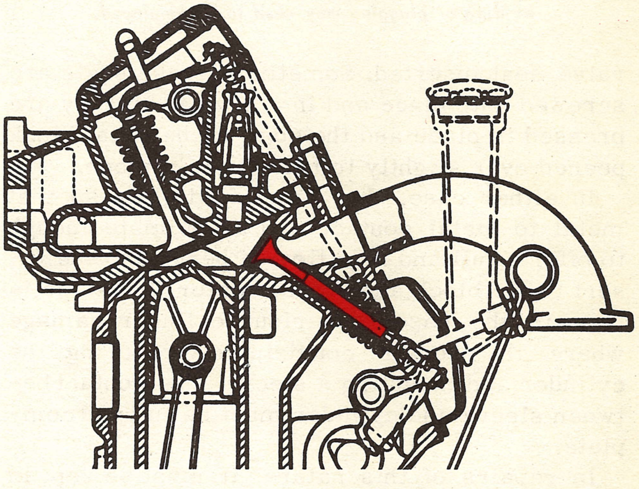


13-9. Here a flat head is used with an angle block and the combustion chamber is mostly in the piston head.



13-10. In this case, very little of the combustion chamber is in the piston head.

A somewhat similar construction with a different valve arrangement is found in the English Rover engine. See Fig. 13-11. In this case the exhaust valve is placed in the wide portion of the cylinder wall.



13-11. In the Rover engine, the angle is so wide that the exhaust valve is placed therein.

On any engine with the head cut at an angle in such fashion, it is necessary to have angular adapters for the cylinder reconditioning equipment if it is located from the block face.

The previously mentioned Rover engine (and some other engines) has a thin deposit of hard chromium in the upper part of the cylinder bore to reduce wear at this point. If the cylinders are rebored, it will be necessary to start from the bottom of the bore and make the cut heavy enough to remove this chromium plating entirely as it is too hard for cutting tools to handle.

In connection with reconditioning cylinders, it is best to find out what sizes are available in oversize pistons before starting the operation. Otherwise the cylinders may be bored to a size for which stock pistons are not available. This would then involve having the pistons reground to the desired size.

CYLINDER WALL REPAIRS

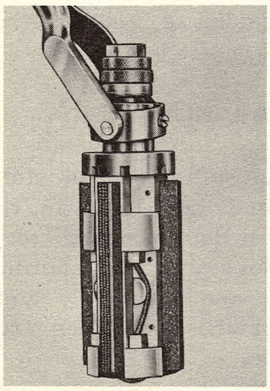
In addition to normal cylinder wear, a piston or pistons may seize or stick in the cylinder due to expansion of the piston caused by overheating, or lack of lubrication, or both. If the piston is made of aluminum, the damage may be mostly to the piston. If, however, the piston is of cast iron, the cylinder as well as the piston may be scratched.

In almost all cases the piston rings will be ruined and new rings cannot be used until the cylinder surface is restored. The scratches or scores will run lengthwise of the bore. If not too heavy, they can be honed out with a suitable cylinder hone. See Fig. 13-12. A hone is not intended to remove any appreciable amount of metal from the bore: it is intended only to clean up and provide the proper surface on the cylinder wall.

Thus if no stock is removed from the bore a standard size piston can be used. If a slight amount of stock is removed by the hone in an attempt to remove heavier scratches, it may be necessary to expand the pistons slightly.

When the scratches are too heavy to remove by honing, it will be necessary to regrind the cylinder bore slightly oversize and fit oversize pistons and rings.

Upon rare occasions a piston pin may become unlocked and slide endwise against the cylinder wall. This will usually produce a deep score in the cylinder wall which cannot be removed by grinding oversize.



13-12. Typical cylinder hone.

In such cases the score may be milled out in dove-tail fashion and a strip of special repair metal or copper pressed in place. The cylinder is then reground, so that the new metal will conform to the shape of the cylinder wall surface. An alternate method is to weld or braze a strip in the groove and refinish the bore.

Still another method is to bore the cylinder out considerably oversize, and press a prepared sleeve of the proper size into the cylinder. Such sleeves have thin walls and must be fitted accurately in the block. If they fit too loose, the heat transfer from sleeve to block will be poor, and the sleeves will overheat and distort. If the sleeve is fitted too tightly, it is liable to be distorted during installation and become out-of-round, or have ridges or "wrinkles" in the bore.

To avoid distortion in the installation of dry sleeves, it is customary to pack the new sleeves in dry ice or store them in a deep freeze compartment for several hours, which will shrink them in diameter enough so that they can be readily and quickly pushed into place.

CYLINDER WALL SURFACE

After installation, cylinder walls should be checked with a suitable cylinder gauge to make sure of roundness, straightness and smoothness. It is desirable to hone these sleeves after installation in order to have a proper surface upon which the rings may seat or "run-in."

The proper surface for a cylinder wall is not a dead smooth or glass like surface. If new rings are installed on a dead smooth cylinder wall surface, they may never seat to the cylinder wall. In such cases the rings cannot control oil consumption or compression blow-by. Furthermore, a new ring in too smooth a cylinder may suffer from lack of lubrication and score the ring face and cylinder wall.

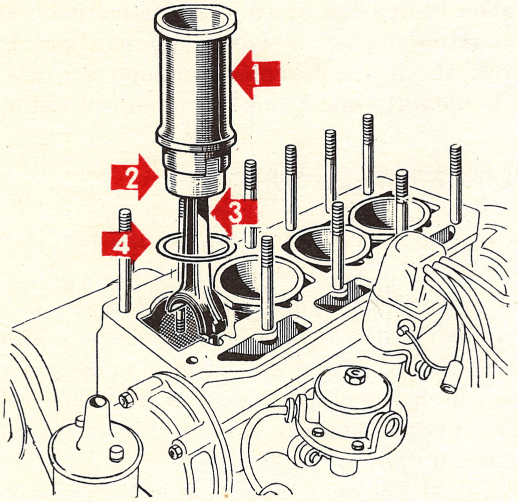
The desired finish is smooth--but not too smooth. It should have a pattern of diagonal cross-hatch scratches, but no longitudinal scratches. This cross-hatch pattern consists of scratches so tiny that they can be measured only in microinches (one millionth of an inch or 0.000001 in.). As repair shops do not have equipment for measuring in microinches, the common practice is to consider the surface correct when it is possible to see--BUT NOT FEEL--the pattern.

Such a finish is obtained with a FEW strokes of a FINE hone; pulling the hone up and down in the bore while the hone rotates. When a hone is not used, abrasive cloth or paper with a fine grit is used.

This delicate interruption of the surface furnishes a mild abrasive action on the ring face to assist it to seat in. Also the exceedingly fine scratches retain a film of oil to provide lubrication for the ring surface and prevent scoring.

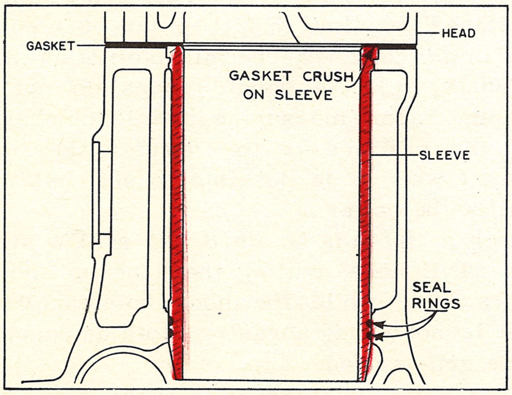
WET TYPE CYLINDER SLEEVES

Passenger car engines built in the U. S. A. usually have the cylinders bored directly in the engine block; while some truck, tractor, and industrial engines use the wet type of cylinder sleeve. A wet sleeve is in the form of a barrel or sleeve which is inserted in the block in contact with the cooling water. Several European passenger car engines have liners or inserted sleeves. An example of this is the 4CV Renault built in France. See Fig. 13-13.



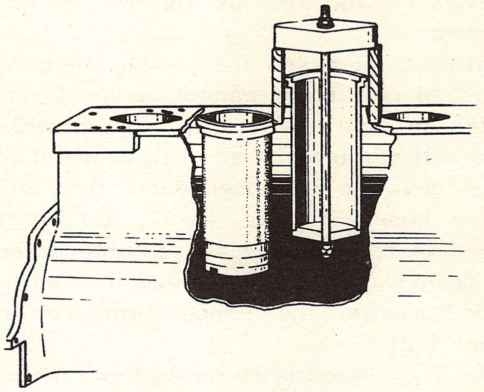
13-13. Wet type sleeve as used by Renault. 1-sleeve; 2-piston; 3-connecting rod; 4-copper sealing ring.

In the wet-sleeve type of construction, each cylinder barrel is a separate sleeve inserted in the block, and sealed at the bottom of the water compartment by means of a copper or rubber gasket. See Fig. 13-14. The cylinder head gasket of course provides a seal at the top end of the sleeve. In this construction, the engine coolant circulates directly around and in contact with the sleeve. As the thickness of the sleeve or cylinder wall is uniform, it is felt that cylinder wall distortion is thus minimized.



13-14. Rubber seals are used at the bottom of the sleeves in this Oliver tractor engine.

Another advantage of cylinder sleeves is of course the ease and comparative low cost of replacing a damaged cylinder bore. These sleeves are easily pulled out, Fig. 13-15, and a new sleeve slipped in place.



13-15. Method of removing wet type sleeves.

The foregoing advantages apply to most air cooled automobile engines, as the cylinders are usually in the form of sleeves or barrels. The Corvair and the Volkswagen are both good examples of this type of construction. Each cylinder is simply a tube with cooling fins on the outside. One end of this tube fits into a recess in the crankcase, and the other end fits into a recess in the cylinder head.

PISTON CLEARANCE

There is no set rule on the amount of clearance to be provided between the piston and cylinder. Much depends upon the design of the engine cylinders and the cooling system, the piston design and material, and to a certain extent the service conditions under which the engine operates.

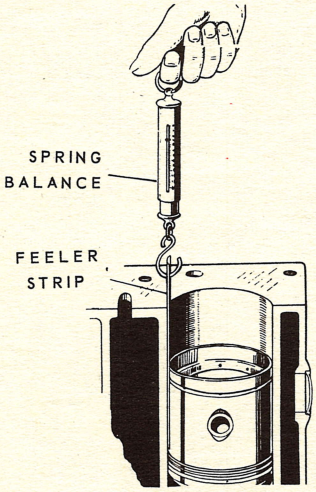
For example, if it is a passenger car engine that will be driven mostly at slow speeds in city traffic, the pistons can be fitted with a minimum of clearance. If the engine is in a fire department pumper, it may be required to stand in one spot and run at full power for hours at a time. Such service would generate a great amount of heat in the cylinders, cause the pistons to expand considerably and thus require the maximum clearance.

In general, it is customary to fit solid skirt cast iron pistons to about .00075 to .001 in. per inch of piston diameter. A four inch piston would thus be .003 to .004 in. smaller than the cylinder. Some aluminum pistons can be fitted more closely but much depends upon the design of the piston. The instructions of the manufacturer should be obtained and followed.

Surface treatment will also have a bearing on the piston clearance. Some pistons are tin plated, others have an oxide coating or some other surface treatment. Sometimes the surface is serrated or interrupted to provide minute pockets for the retention of oil. These treatments are intended to lessen the tendency of the piston to stick or score, most particularly during the time it is seating to the wall.

CLEARANCE MEASUREMENT

The clearance between cylinder and piston is measured in most cases by means of a feeler gauge inserted between piston and cylinder. See Fig. 13-16. The strip of feeler gauge should be about 1/2 in. wide and long enough to extend the full length of the cylinder. This strip of a thickness equal to the desired clearance should be placed on the thrust side of the skirt. Four to five pounds pull as measured on a spring scale should be required to remove the feeler.



13-16. Method of using spring scale with feeler strip to check piston clearance in cylinder.

The clearance can also be measured by subtracting the maximum diameter of the piston from the minimum diameter of the cylinder as measured by inside and outside micrometers. In this case, measurement must be made at several points in the cylinder and on the piston. All piston clearance recommendations are made for use with the temperature approximately 70 deg. F.

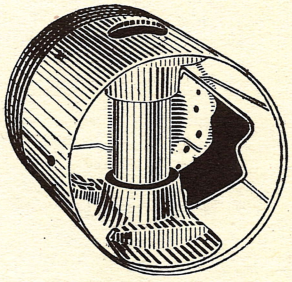
As pistons wear, or if they become overheated, the skirt is liable to collapse or become smaller in diameter. When this happens the piston will "slap" in the cylinder, and will also allow an excessive amount of oil to pass up to the rings. This of course places an undue load on the oil control rings, and may result in oil pumping.

PISTON RESIZING

There are several ways to expand or resize the pistons. One method consists of heating the piston, and expanding it with special equipment made for the purpose. Another method requires special equipment for "peening" the inside of the piston with steel shot. This procedure compacts the metal on the inside and causes it to expand on the outside. Electric and pneumatic peening hammers are made for the same purpose.

Various types of equipment or tools are available for "knurling" the piston skirt. This method raises the surface of the metal in ridges or patterns along the path of the knurling and thus increases the diameter of the piston. An additional claim made for this method is that it creates "pockets" on the piston surface, which gather and retain a film of oil to assist in sealing and lubricating.

Another procedure is to install piston expanders inside the pistons. There are a great number of these devices on the market. They vary in design, but usually consist of a steel spring strut that is compressed and installed in such a way it exerts internal pressure on the split piston skirt. See Fig. 13-17.



13-17. This type of piston expander pushes outward on each of the piston bosses.

Such expanders are often effective for collapsed pistons, but they should not be installed in only one of the cylinders. If used, they should be installed in all pistons of any one engine because of balance requirements. The expanders are made as light in weight as possible, but most automobile engines have pistons matched in weight at the factory to a few hundredths of an ounce. Any replacement pistons should also be carefully matched for weight with the other pistons as otherwise engine vibration may occur.

QUIZ - ENGINE RECONDITIONING

1-Name five ways of increasing the size of a metal part.

2-An oversize bearing is required on a reground crankshaft journal. True---, False---.

3-Name five ways of repairing a water jacket cracked by freezimg.

4-How much warpage can usually be tolerated in a cylinder head or block? .020---, .030---, .045--- in.

5-Angular blocks must be rebored from the bottom of the bore. True---, False---.

6-Why do pistons sometimes seize in cylinders?

7-Name two ways of repairing badly scored cylinders.

8-Why must dry cylinder sleeves fit tightly in the block.

9-If a newly installed dry sleeve is round, straight, smooth and free from wrinkles, is it ready for service? Yes---, No---.

10-A properly fitted ring in an undamaged cylinder may never seat. True---, False---.

11-What is a microinch? .0001---, .00001---, .000001 in.---.

12-How can a proper cylinder wall finish be described?

13-A wet type cylinder sleeve should be frozen before installation. True--- False---.

14-In general, cast iron pistons should have about .0075 to .01---, .00075 to .001---, .00005 to .00015--- in. per inch diameter clearance in the cylinders.

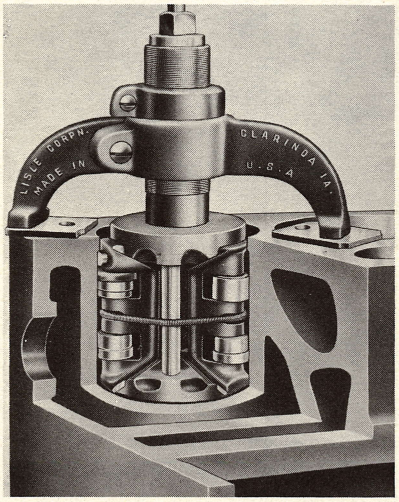
15-Name three ways of expanding pistons.

16-Piston expanders should always be used in sets. True--- False---.

PISTON RING FITTING

Previously in this text, we have studied piston ring design and purpose. We have also noted that a ridge is formed at the top of the cylinder wall as the cylinder wears. To avoid damage to pistons and rings, this ridge should be cut away before an attempt is made to remove the pistons from the cylinders. Special tools are made for this purpose as shown in Fig. 14-1.

We have also considered cylinder wall reconditioning and piston fitting. We must now devote some consideration to proper fitting of the rings to the piston and cylinder, and also to fitting of the piston pins in the pistons.

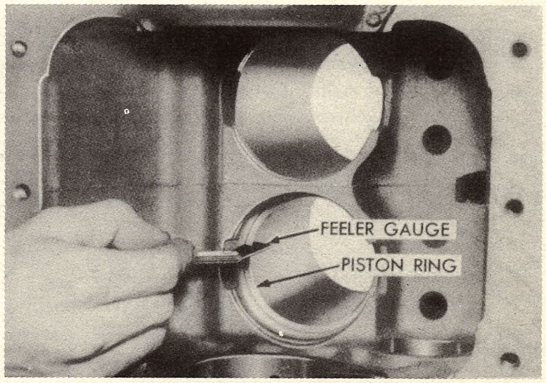


14-1. One type of special tool as used for removing ridge at top of cylinder.

PISTON RING GAP

It is obvious that the top piston ring runs hotter than the lower rings, and therefore the top ring will expand the most. This means that the top ring will need more gap clearance at the ends, and more sidewise clearance in the piston grooves than the other rings. The piston ring manufacturer specifies the clearance needed, and his instructions should be followed.

Piston ring gap clearance is measured as shown in Fig. 14-2. The ring is pushed into the smallest diameter of the cylinder bore, which is usually below the travel of the bottom ring. A piston without rings is used to push the ring in place as this method locates the ring squarely in the bore. The rings should be purchased for the correct size to avoid fitting. Minor increases in gap clearance can be made by filing the ends of the ring. This should be done carefully with the aid of special tools made for the purpose.

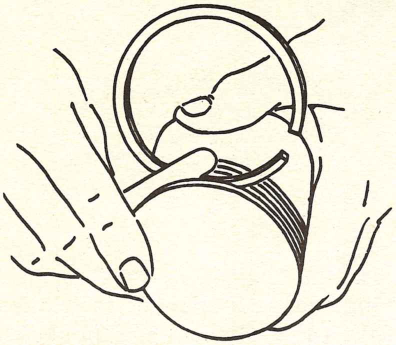


14-2. Piston ring gap should be measured with the rings seated squarely in the smallest diameter of the cylinder.

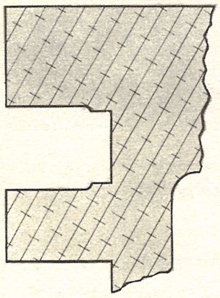
In case specific clearance dimensions are not available, it is customary to allow .004 in. gap clearance per inch of piston diameter for the top ring, and .003 in. per inch diameter on the other rings. For example, a three inch diameter cylinder would require .012 in. gap on the top ring, and .009 in. on the other rings. The exception to the foregoing is the "U" type oil ring that is extremely flexible. These rings are flexible endwise and require no gap clearance.

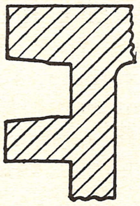
RING GROOVE CLEARANCE

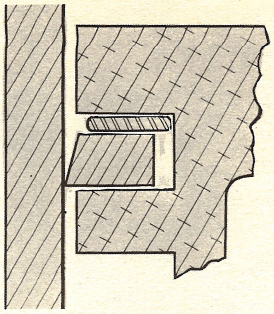
The sidewise clearance of the ring in the groove is measured as shown in Fig. 14-3, using a feeler or thickness gauge. In the absence of specific instructions, it is customary to allow at least .003 in. side clearance on the top ring and at least .002 in. on the other rings. More than .005 in. side clearance on any ring calls for new rings.


14-3. *Method of measuring sidewise clearance of ring in grooves.*

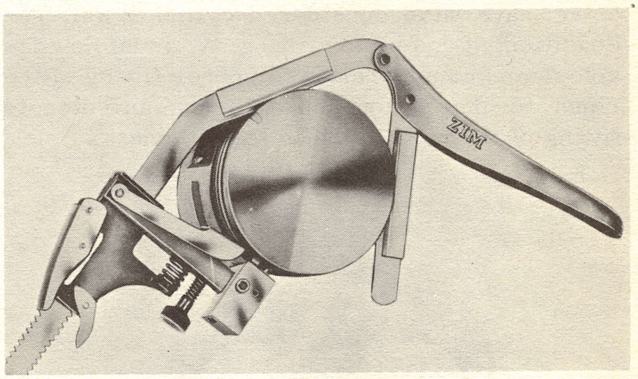
New rings can be purchased in almost any size as well as oversize and overwidth as desired. Overwidth rings may be used if the sides of the ring grooves are flat, smooth and square. If the grooves are worn excessively as shown in Fig. 14-4, or in tapered fashion as shown in Fig. 14-5, they can be repaired in two ways. One way is to machine the grooves out wider and install overwidth rings. The other way is to install spacers with standard width rings as shown in Fig. 14-6. In either case the ring grooves in the piston will need to be trued up. Special equipment is available for this purpose. See Fig. 14-7.


14-4. *The shoulders in the bottom of the groove might not leave clearance for new rings.*


14-5. *The usual wear pattern is tapered in form.*

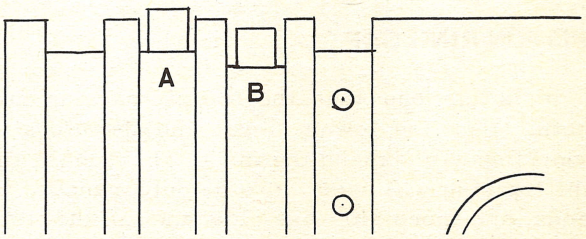

14-6. *Standard width rings may be used with a spacer in remachined grooves.*

The depth of the ring groove must be checked also when replacing rings. Sometimes shallow grooves are used with thin rings, and a replacement with normal thickness rings will cause them to "bottom." The groove must be deep enough to allow the ring to enter the groove below the surface of the ring land. See Fig. 14-8. If the grooves are too shallow, they can be machined out deeper.



14-7. *One type of special ring groove tool.*

Sometimes rings turn slightly in the groove, and sometimes they do not. When installing rings, the gaps are usually spaced around the pistons, to avoid any possibility of the gaps



14-8. *The ring should fit freely in the ring groove below the surface of the lands as shown at B.*

getting one above the other and encouraging blow-by.

The manufacturers' instructions should always be followed when installing new rings. They know how their own products should be fitted, and they have studied the peculiarities of the different engines. For example, one type of piston has a wide slot in the bottom ring groove. If an expander type of ring is placed in this groove, the expander may fall into the slot. For this reason, the manufacturer supplies a set of "bridges" to be placed in this groove to support the expanders.

Piston rings are fragile and must be handled carefully. They should be placed in the piston ring grooves with the aid of a ring tool and not by stretching them over the piston. Even if they do not break, they may become so distorted by careless handling as to be useless. It is also important to use a ring compressor when inserting the piston with rings into the cylinder. Otherwise the sharp edge of the ring may be deformed and the ring rendered useless. See Fig. 14-9.

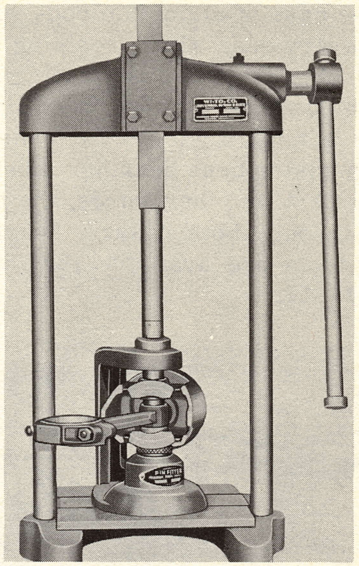
In any case of doubt as to the proper clearance for rings and pistons, it is safer to err on the side of too much clearance rather than too little. In this connection, it is all too often assumed that an engine pumps oil because of worn piston rings. Times without number new rings have been installed only to have the engine pump oil worse than ever.

14-9. One type of piston ring compressor used to hold rings in place while installing pistons.

If the bearings are worn in a pressure lubricated engine so that an excess of oil is thrown up in the cylinders, the engine will pump oil regardless of how good the rings are or how well they are fitted. The oil simply gets on the cylinder walls and pistons in such quantities, that it is beyond the ability of any ring to control it. This will be further explained in the section on bearings.

PISTON PIN REPLACEMENT

It is the usual thing to find wear in both pin and bearings when piston pins become loose.



14-10. Piston bosses should be supported when pins are pressed in or out.

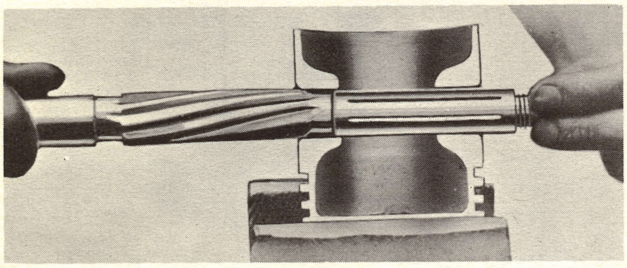
Where the bushing is in the connecting rod only, it can be pressed out and a new standard size bushing pressed in and reamed or honed to fit a new standard size pin. The old bushing should not be removed with a hammer and drift, as there is danger of bending the connecting rod.

Where the pin is clamped in the rod and the bushings are in the piston bosses, the same method can be used. When replacing bushings in the piston, it is extremely important to avoid hammering, as the piston can be easily distorted by rough handling. The piston boss should be supported firmly in the press while the old bushings are pressed out and the new bushings pressed in. See Fig. 14-10.

OVERSIZE PISTON PINS

If it is decided to install oversize new pins, and ream or hone the old bushings in the piston to fit the oversize pin, the connecting rod clamp hole will need to be enlarged accordingly. This condition also arises where the pistons are not bushed, and the pin bearing is directly in the piston bosses. If difficulty is experienced in reaming the rod end due to the split for clamping, a shim may be placed in the slot, and the clamp bolt drawn down tight. The shim will have to be the same thickness as the opening in the slot when the rod is clamped on the standard size pin. The inner edge of the shim should be flush with the hole so that the reamer will cut both shim and rod.

In the full floating type, the installation of new oversize pins will require reaming or honing of the piston bushings or bosses, and the bushing or rod (in the case of aluminum rods without bushings). In every case where reaming or honing is done on either piston or connecting rod, it is of utmost importance to have the finished hole at precisely a right angle to the connecting rod. Also both piston boss bearings must be in precise alignment. In other words, the hole must be straight through both bosses. Special aligning types of tools are available for this purpose. See Fig. 14-11.



14-11. Aligning type of reamer used to insure straight holes in both piston bosses.

PISTON PIN FITTING

Fitting piston pins is one of the most delicate operations to be found in automobile repair work. Millions of pins have been improperly fitted--and are still being improperly fitted. The reason for this is that suitable equipment for fitting piston pins properly is a comparatively recent development.

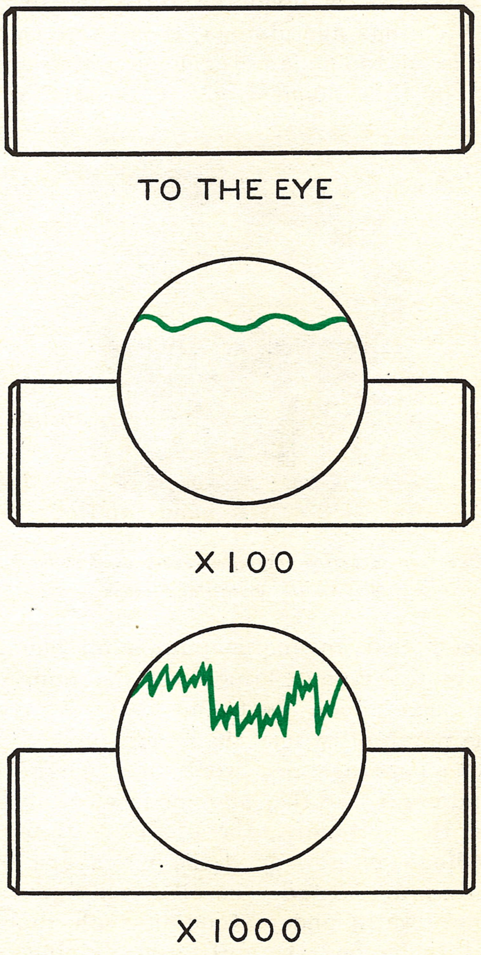
Accuracy measurements in thousandths and tenths of thousandths is fairly common in automobile repair work. However in dealing with piston pins we are splitting up the tenths. We are dealing with microinches or millionths. In fact it is useless to use the term microinch in most cases without specifying the temperature at which the measurement is made. This is because a few degrees rise or fall in the temperature will expand or contract the metal enough to change the measurement given in microinches.

Furthermore, as previously mentioned, we are dealing with steel, bronze and aluminum, each of which has a different rate of heat expansion. We fit the piston pins at room temperature (assumed to be 70 deg. F.) and then put them in an engine which quickly attains a temperature of at least 140 deg. F. This temperature expands the pin, the bushings, if used, and the piston. If it is a cam ground piston it also changes shape from oval when cold to round when hot.

This change in shape of the piston may also disturb the alignment of the two holes in the piston bosses. If we had a round, straight hole through the two bosses--which would stay round and straight when hot--and a round and straight pin to fit, it would then be only a matter of suitable clearance for the oil film. There must be room for a film of oil around the piston pin. Otherwise metal-to-metal contact will occur and the friction thus generated will score the pin or bushing or both.

Standards of manufacture have improved and most piston pins are round and straight within one tenth of a thousandth of an inch. A pin so finished looks perfect and appears to be glass-smooth. When the surface is magnified 100 times it does not look so smooth and when magnified 1,000 times it looks rough indeed. See Fig. 14-12.

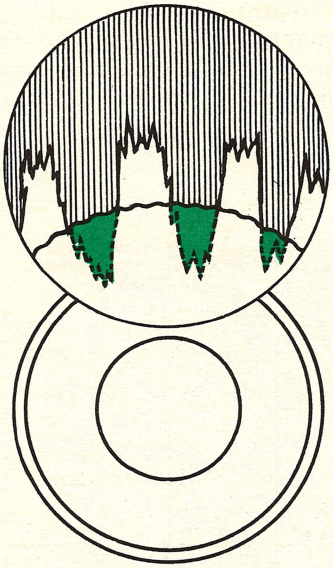
Reaming, grinding and honing equipment is now available which will produce a hole which



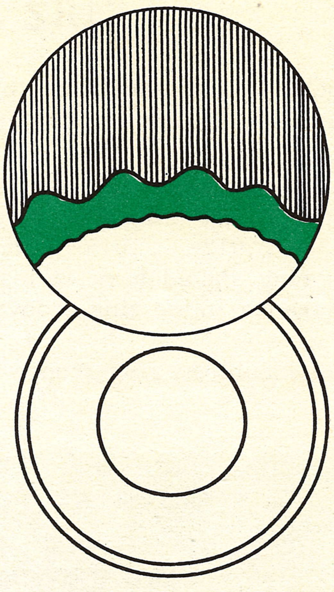
14-12. An apparently smooth pin may be rough indeed when magnified on the surface.

appears to be dead smooth. It is, like the pins, accurate to one tenth of a thousandth, but when magnified it looks much like the bearing surface on the pins. It is possible, however, with the use of good equipment to produce a hole that enables a good working fit to be made. It should be obvious that in working with such close dimensions, the clearance will be determined by the surface finish.

If the hole finish is not practically perfect, it will be seen that when the pin is forced into the hole the "peaks" will be sheared off as shown in Fig. 14-13. The result of such a condition is rapid wear of the peak base, and the pin and bushing are worn OUT before they wear IN to a working fit.



14-13. Forcing a smooth pin into a rough hole will cause the high points of the peaks to be sheared off and we will actually have metal-to-metal contact between the pin and parts of the bushing.



14-14. A proper surface on the pin and in the bushing should result in space for an oil film between the two.

In this connection, it has been found that many experienced mechanics fit piston pins entirely too tight. These same mechanics often wonder why many of the jobs they do develop knocks and rattles and pump oil in a short time. The reason is, of course, that the tight fit they insist on having results in the condition shown in Fig. 14-13 with consequent rapid wear.

If the hole is properly finished to the proper size, there will be room for a film of oil to prevent metal-to-metal contact and thus reduce wear. See Fig. 14-14. When such a fit is obtained, the pin will enter the hole readily without force being applied, and will have a sufficient bearing surface to wear satisfactorily. Such a fit can be obtained by a skillful operator using modern equipment in accordance with the manufacturers' instructions.

QUIZ - PISTON RING FITTING

1-How much end gap should the top ring have in a four inch diameter cylinder? .009---, .012---, .016--- in.

2-How much gap should the oil ring have in a cylinder three and one half inches in diameter? .009---, .012---, .015--- in.

3-The top ring should have at least .005 in. side clearance in the ring groove. True---, False---.

4-How deep should the ring groove be?

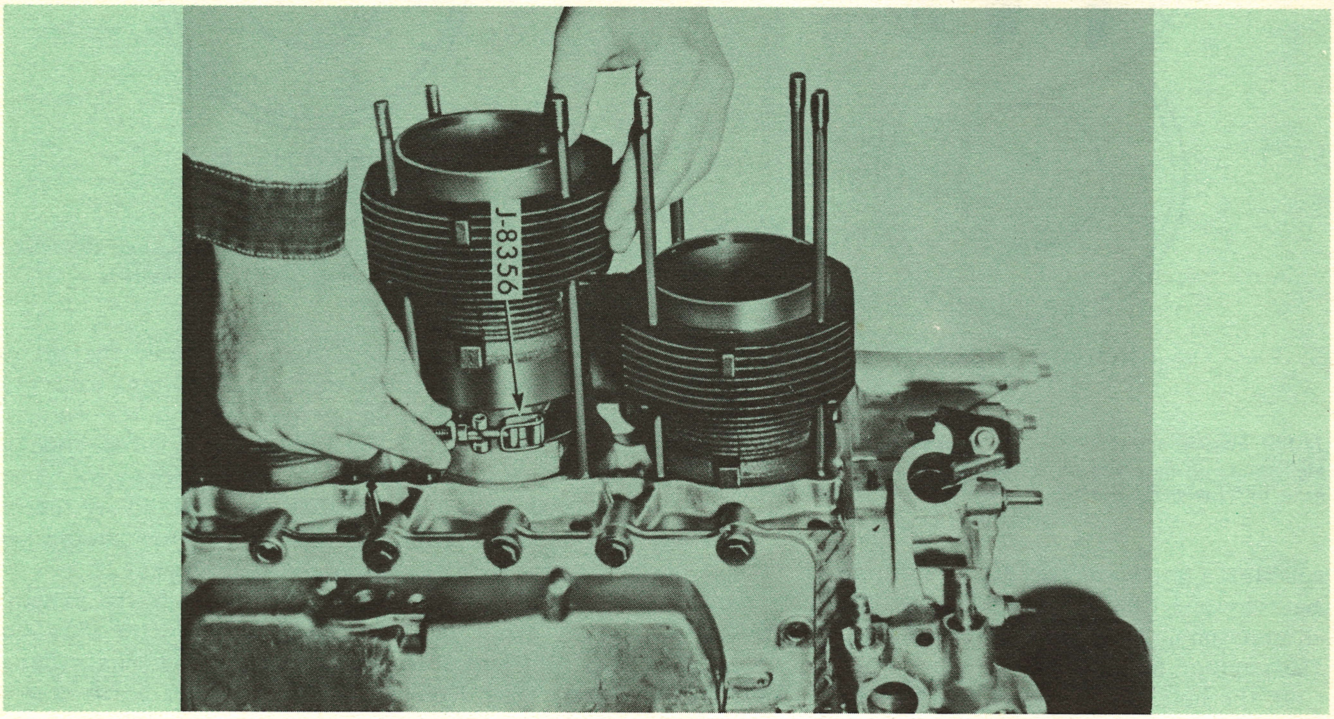
5-Piston pins are casehardened, so do not wear. True--- False---.

6-Can oversize pins be installed when the pin floats in both piston and connecting rod? Yes---, No---.

7-What is meant by "room temperature?"

8-New piston pins can be expected to be round within: .002---, .0001---, .00005--- in.

9-New piston pins are often fitted: too tight---, too loose---.



Special type of piston ring compressing tool as used to install barrel cylinders on Corvair.

CRANKSHAFT WEAR

While engine crankshafts are very sturdy, they do sometimes need attention after long continued use. We have seen that the forces applied to the journal are much heavier at some points of rotation than at others. For example, the force of the explosion is several times as strong as the force of the compression stroke. Also the explosion stroke applies the force always at the same spot on the journal. This tends to cause a "flat spot" or out-of-round condition on the crankpin journal.

If a connecting rod is bent, or is out of alignment, it will tend to wear the crankpin journal in a tapered fashion--that is, more at one end of the bearing surface than the other end. Also any twisting of the engine crankcase or any excessive vibration of the crankshaft will tend to cause the main crankshaft journals to wear in tapered form.

Furthermore, if abrasive material gets into the oil the wear may be unequal, more at one bearing or more on one spot of the bearing depending on which bearing, and where on the bearing the abrasive enters in greatest quantity.

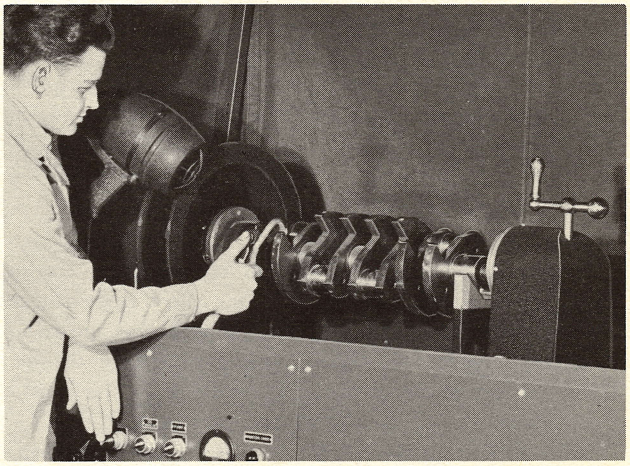
Bearings seldom wear equally for these and other reasons. One bearing may operate with a smaller volume of oil than another. Likewise, one bearing, due to its location in the engine, may operate at a higher temperature than the others. All of these things cause or contribute to unequal wear on the crankshaft journals.

If a connecting rod journal has the least taper, or has a flat spot on it, it simply cannot be used. Such a condition would ordinarily cause such an increase in oil consumption that it would be essential to recondition the crank throw.

Due to close clearances in the bearings, a sprung crankshaft cannot be tolerated. The main bearings must fit the crankshaft journals all around the circumference with only enough clearance for a film of lubricating oil. If the bearing journal is scored or other than absolutely round, it cannot be used until it is reconditioned or replaced.

DAMAGED CRANKSHAFTS

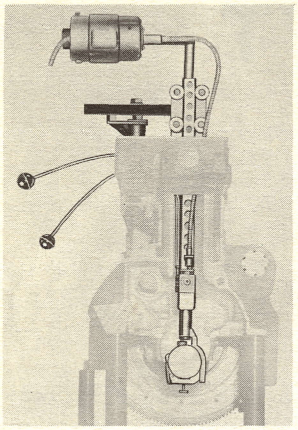
As engine crankshafts are usually large and expensive parts, it is often desirable to repair damage rather than replace them. Before any extensive work is started however, it is well to have the shaft checked by a specialist with proper special magnetic or chemical equipment to make sure there are no invisible cracks in it. See Fig. 15-1.



15-1. With the "Magnaflux" method the part is sprayed with a material that will show any fracture by glowing under the hood which shuts out some of the light.

In case damage has occurred to one or more crankpin journals and the crankshaft is not removed from the engine, it is possible to recondition the crankpin with the aid of special equipment made for this specific purpose. See Fig. 15-2.

An engine crankshaft is subjected to terrific vibration and stress and may develop tiny cracks, particularly at or near the ends of the connecting rod throws or at the ends of the main bearing journals. Occasionally an invisible crack may develop near the oil feed holes in the shaft.



15-2. *One type of special equipment for machining connecting rod journals with the engine in the car.*

If the crankshaft is sound and the journals are worn slightly taper or out-of-round, the shaft journals can be reground and undersize bearings fitted. See Fig. 15-3. Here again, as in the case of reboring cylinders, it is desirable to find out the available sizes of bearings that are carried in stock so that the extra work of boring the bearings to fit the shaft will be avoided.

If the shaft is badly damaged but a new shaft high in cost, it is possible to restore the journal by spraying metal on it. It is built up oversize and then reground to the desired size. This work is usually done by specialists. See Fig. 15-4.

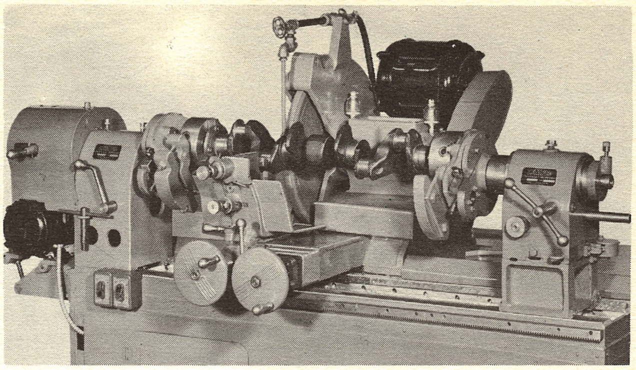
WORN CAMSHAFTS

Some wear does occur on camshafts, as on any other engine part, but as they operate at slower speed than the crankshaft the wear is usually slower. As the entire shaft is hardened, the bearing wear ordinarily occurs in the bushings rather than on the shaft journals.

Aside from a defective camshaft, or a lubrication failure, the wear on the cam lobes is quite slow. If a check on the valve lift shows that it is less than it should be, the cams can be reground on special machinery. In most cases however, the camshaft is replaced.

BEARING CLEARANCES

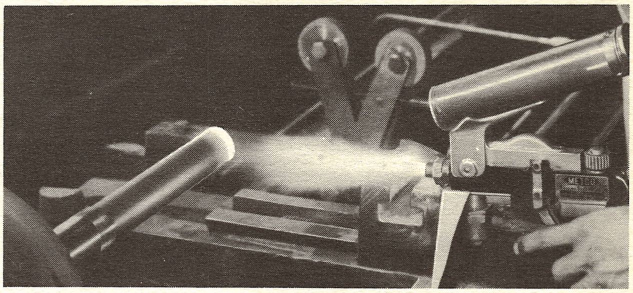
In our previous study of lubrication, we found that oil is pumped under pressure to the various bearings in the engine. In order for this oil to get into the bearing and lubricate it, clearance for an oil film must exist.



15-3. *This is a special machine for grinding a true surface on crankshaft journals.*

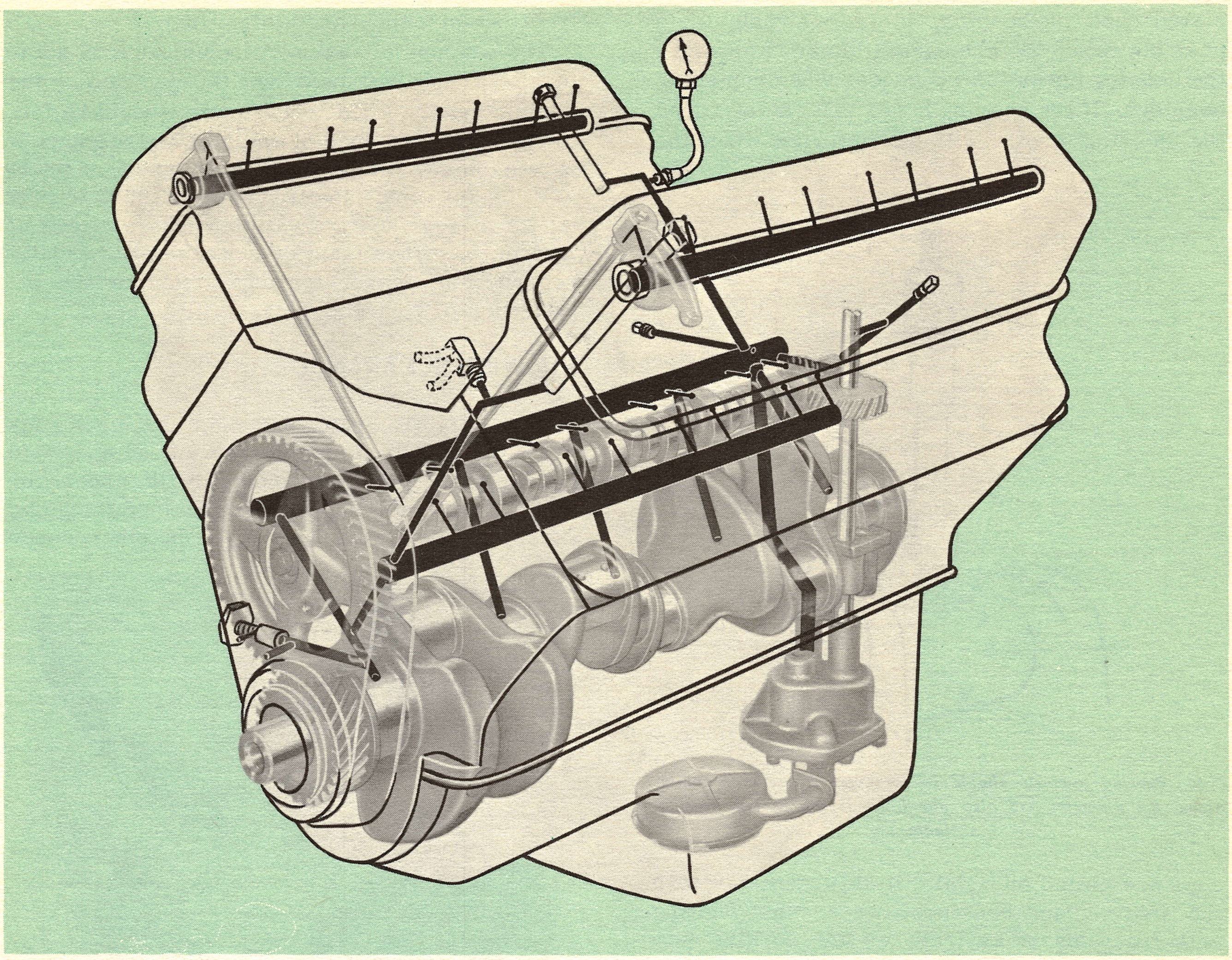
The one most important thing to keep in mind in this connection is that the steel crankshaft journal MUST be separated from the bearing metal when the engine is running or the bearing will melt. The heat generated by friction when steel moves rapidly on soft dry metal WILL melt the soft metal--almost at once. Therefore in an automobile engine we use a film of oil between the journal and the bearing. THERE MUST BE SPACE PROVIDED FOR THAT FILM. The film serves to hold the two metals apart and also circulates to carry away the heat generated by friction. The space is not great--it is measured in thousandths--but those thousandths are all important.

This film thickness will vary with the design of the engine and the type of lubrication system used. In general, a splash lubrication system is less critical of oil clearances than a pressure lubrication system. In the splash system, the oil in the pan is churned up by the internal parts of the engine into a combination of liquid and mist which is sprayed over the entire interior of the engine.



15-4. *Metal worn away can sometimes be replaced by spraying new metal on with special equipment. The part is then refinished to size.*

Some of this oil, in a splash lubricated engine, is collected in pockets above the main bearings, and flows through the bearing by means of



15-5. A typical full pressure oil circulation system carries the oil to practically all of the working parts.

grooves in the bearing surfaces. The connecting rods dip into the oil and obtain lubrication. These bearings can be operated when slightly out-of-round, and are usually made adjustable for wear.

In the pressure lubricated engine, the oil is pumped under pressure to the bearings. See Fig. 15-5. In this case, we must control the flow of oil by maintaining limited clearance all around a ROUND bearing and a ROUND shaft. If we have unequal clearances in the circulation system, we will have too much oil in one place, and not enough in other places. This is because the oil being under pressure will go through the largest clearance space in the greatest quantity.

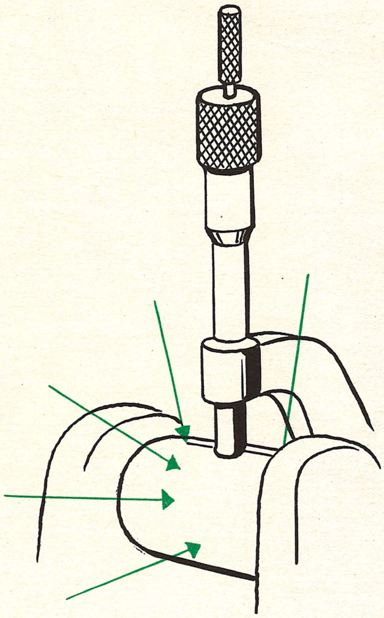
CLEARANCE MEASUREMENT

One method of measuring oil clearance is to measure the diameter of the journal with a micrometer caliper, the use of which is described elsewhere in this text. The diameter of the shaft is measured at several points around the circumference to determine the size and to check for roundness. See Fig. 15-6. It is also measured at each end of the bearing surface to determine the amount of taper, if any.

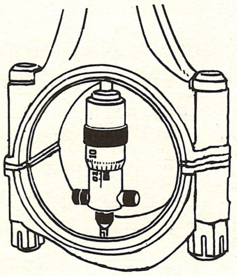
The inside of the bearing is then measured with the cap bolted in place, using a telescoping gauge or an inside micrometer. See Fig. 15-7. The difference in these two measurements represents the clearance between the journal and the bearing.

An alternate method is the use of a plastic material which deforms or flattens between the journal and the bearing when the cap is drawn down to the proper tightness. The amount of increase in the width of the plastic material as it flattens out, is then measured with a gauge provided to determine the clearance between journal and bearing. See Fig. 15-8.

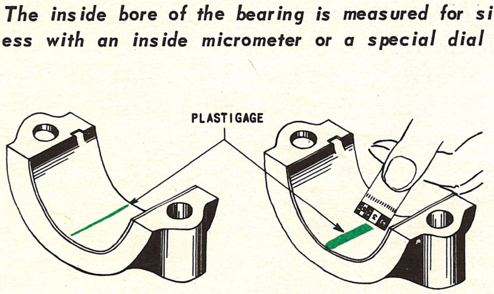
With the integral type of bearing it is not possible, or necessary, to measure the bearing bores with the bearing in place. With the precision type of bearing, it is desirable when possible (when the crankshaft is out) to measure the bearing bores for roundness when replacing bearings. If the bearing bores are out-of-round the bearing shells will be distorted when the caps are bolted on tightly. In this case--as with the journal and bearings--we are not dealing with fractions of an inch; we are working with fractions of a thousandth of an inch.



15-6. *Bearing journals should be measured at several points around the diameter and also along the length of the bearing surface.*



15-7. *The inside bore of the bearing is measured for size and roundness with an inside micrometer or a special dial gauge.*

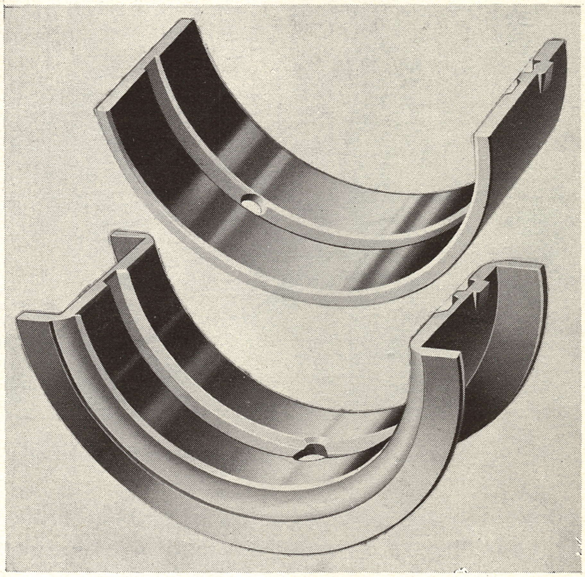

PLASTIGAGE
PLASTIGAGE IN PLACE BEFORE BEARING CAP IS TORQUED.
PLASTIGAGE AFTER BEARING CAP IS REMOVED.

15-8 *Method of using plastic material to check bearing clearance.*

The amount of diametral clearance on automobile crankshaft bearings is specified by the manufacturer. These dimensions should be followed. In the absence of specific instructions, it is customary to use a minimum of .0005 to .001 in. for small shafts and up to .0015 to .002 in. for a large shaft. Any clearance in excess of .005 in. on either main or rod bearing is usually regarded as reason for adjustment or the installation of a new bearing.

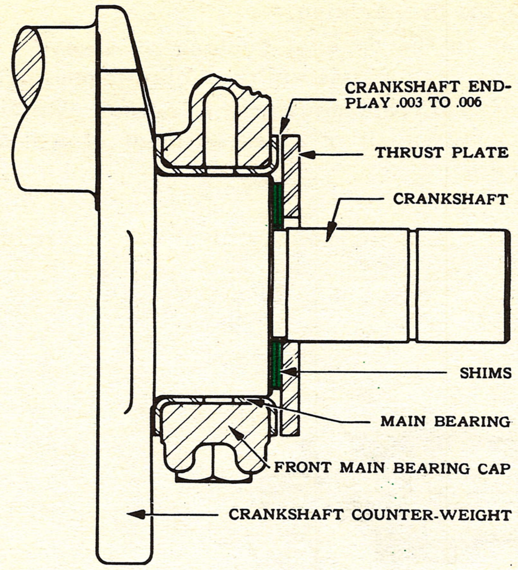
ENDWISE CLEARANCE

Obviously the crankshaft must not move endwise to any great extent; so one of the main bearings is usually provided with cheeks or flanges that bear against a machined flange on the crankshaft. See Fig. 15-9. In other cases bronze washers are installed to absorb the end thrust. See Fig. 15-10. There is always some end thrust on the crankshaft. This may originate in the clutch pushing against the end of the shaft, or the thrust of the helical teeth on the timing gears, or both.



15-9. *Plain and flanged types of shell bearing inserts.*

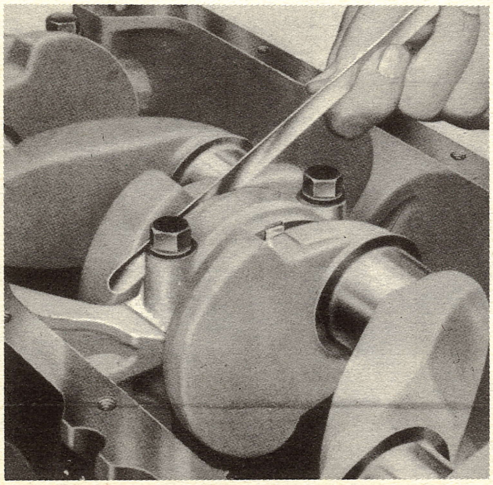
Just as in the case of diametral clearance, there must be some clearance on the thrust faces. Otherwise expansion of the shaft and bearings from the normal heat of operation would cause metal-to-metal contact and burning of the thrust bearing. Here again the car manufacturers' instructions should be followed. In general, it is customary to provide a minimum of .004, and a maximum of .008 in. clearance. End thrust can be measured with a feeler gauge as shown in Fig. 15-11.



15-10. Bronze washers are also sometimes used in connection with shims to regulate endwise motion of the crankshaft.

INTEGRAL BEARING REPLACEMENT

In the case of poured or integral bearings, it is possible to ream or bore them straight and true to whatever dimension is wanted. This is made possible by tools of great accuracy which are now available. At one time it was necessary to fit the bearing to the journal surface by a laborious method known as scraping which required considerable skill. Modern boring equipment has sufficient accuracy to produce almost a 100% surface contact with each bearing in precise alignment. The boring is done with the bearing caps and shims, if used, all in place and the bolts drawn down to the specified torque.



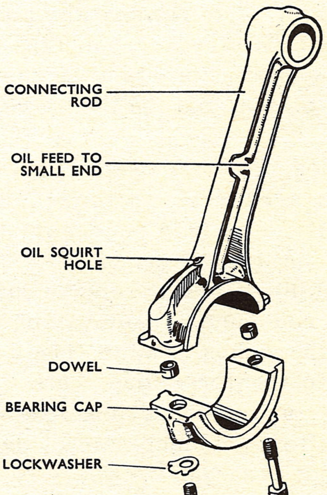
15-11. Usual method of checking endwise clearance of crankshaft. A suitably mounted dial gauge can also be used.

One advantage of the integral main bearing design is that new bearings will compensate for any warpage that may have occurred in the crankcase as the boring bar will cut a straight hole through all the bearings. One disadvantage is the great amount of work required to replace the bearings as compared to the shell type of bearing.

Poured bearings are still in use to some extent for connecting rod bearings. One reason for this is perhaps the feeling that the heat flows from the bearing surface to the rod more readily because of the close bond between the bearing metal and the rod. One disadvantage is that replacement of the bearing and rod assembly usually requires removal of the cylinder head, piston, rings and rod assembly. Few engines permit removal of the pistons and rings from below.

CONNECTING ROD REMOVAL

In this connection, it is quite a chore to get the rods out of some engines. On many small bore European engines, the big end of the connecting rod is too large to go through the cylinder bore. In some cases the engine has removable cylinder sleeves which when removed will allow the rod to come through the block opening. In many cases the rod is split at an angle as shown in Fig. 15-12 to facilitate removal. It will be noted that cap screws with locking plates, rather than studs or bolts, are used to hold the rod bearing cap in place with this type of construction.



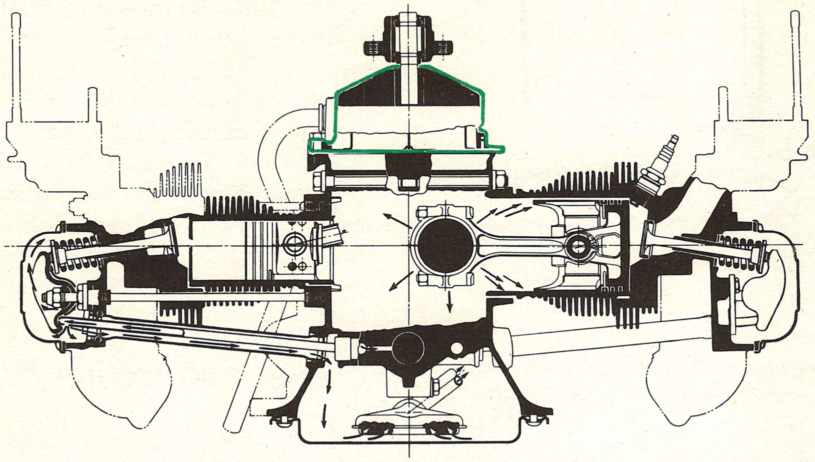
15-12. Connecting rods are split at an angle to permit removal from above.

One English engine--used in the Armstrong

Siddeley--is so designed that the crankshaft must be removed in order to get the pistons out of the engine. In this case, the pistons will not clear the crankshaft in the crankcase, and the connecting rods will not clear the cylinder bores. Later models have removable cylinder sleeves which when removed allow the piston and rod assembly to come out from above.

A somewhat similar situation is found on the English Riley; the connecting rod will not come out through the cylinder bore, and the piston will not clear the crankshaft. The solution in this case however, is to remove the connecting rod cap and push the piston up out of the bore on top. The floating piston pin is then easily removed to free the piston, and the rod is removed from below.

The opposed, or pancake, type of engine usually has a barrel crankcase which is split longitudinally, and it is necessary to dismantle the engine to get the rods out. Sometimes it may be possible--with the engine out of the car--to get one rod out by removal of the cylinder barrel on the opposite side. The Corvair is an exception to the foregoing. This engine has a cover plate on top the crankcase, which when removed, allows replacement of the connecting rod bearings. See Fig. 15-13.



15-13. The Corvair engine has a removable plate on top the crankcase for access to the connecting rods.

REPLACEMENT OF INSERTS

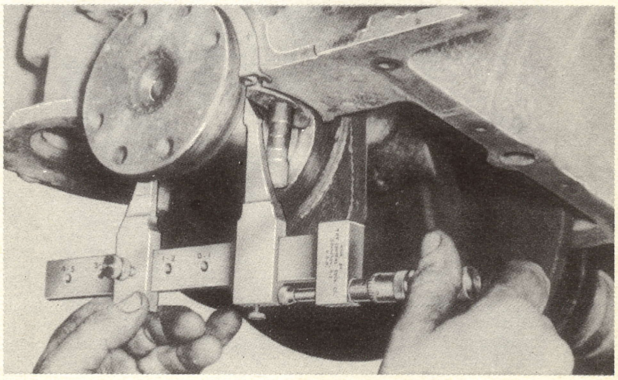
With the insert or shell type of bearing, it is usually possible to replace all main and all connecting rod bearings without removing the crankshaft or cylinder head. See Fig. 15-14. These bearing shells require no fitting by hand, as they are made to extremely close limits of accuracy. It is only necessary to obtain and install the proper size.

Even in the case of bushing or sleeve type bearings such as used in the Volkswagen engine (Fig. 15-15), replacement bearings are available in an assortment of sizes to meet almost any requirement.

If the crankshaft journal is round and smooth, and not worn to any extent, a new standard-size bearing shell is simply inserted in place. If the crankshaft is round and smooth, but worn slightly undersize, a shell of the proper undersize bore is used. If the crankshaft has been damaged, and then reconditioned to a standard undersize dimension, a still smaller undersize bearing is used.

If the crankshaft journal has been reduced in diameter so much that a standard undersize shell will not fit, shells are available with excess bearing metal that can be bored out to the size desired.

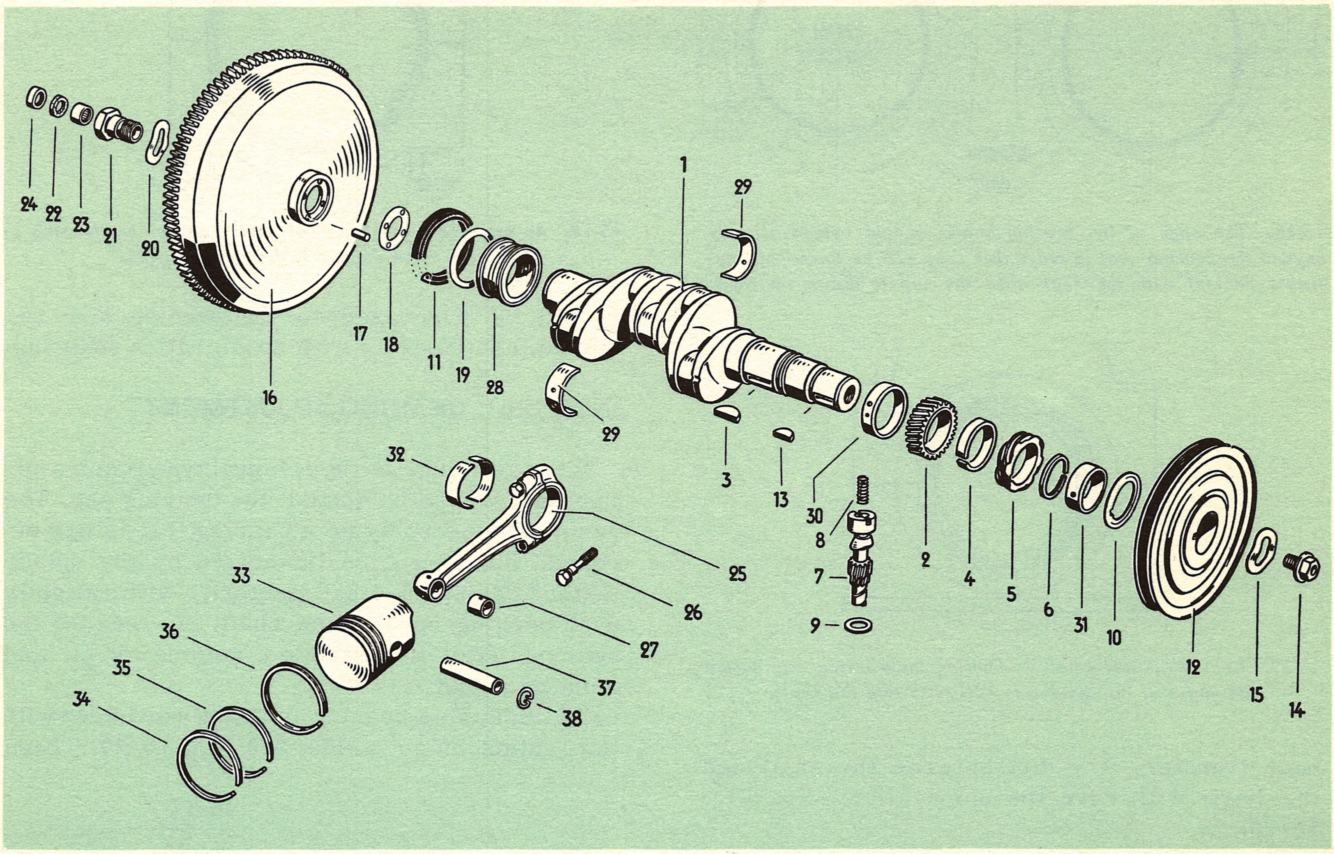
If the bearing bore and journal are round, these new inserts require no fitting or adjust-



15-14. Proper size of the insert needed can be determined with the crankshaft in place by means of this special tool.

ment. If the journal is out-of-round more than .0015 in., it should be trued up or machined until it is round. The same applies to the bearing bore in which the insert seats. Any errors in the bore will distort the bearing shell when the bolts are drawn down to the proper specification.

It is of course, impractical to measure the bore of the main bearing seats with the crank shaft in place to make sure they are round. However, the main bearing caps are heavier and less liable to distort than the connecting rod caps. The connecting rod cap can be installed and bolted down without the bearing shell in it, and measured for roundness or taper with inside micrometers or gauges made for the purpose. If slightly distorted they can be machined true. If seriously distorted, the rod and cap should be discarded, as it is not advisable to remove any appreciable amount of metal which might weaken the connecting rod.



15-15. The rear main bearing (28), the two front main bearings (30 and 31) on the Volkswagen engine are of the sleeve type. The center main (29) is split.

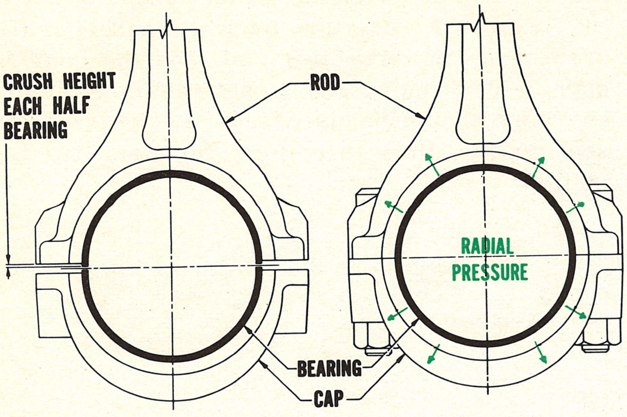
BEARING SHELL SEATING

The bearing seat and bearing shell MUST be round and true, as there MUST be intimate contact between the inside of the bearing seat bore, and the outside of the bearing shell. This is not generally understood as well as it should be. If true and intimate contact does not exist, the heat will not flow from the shell to the crankcase or connecting rod, and the bearing may melt. It may thus be seen that no shims of any sort should be used between the shell and seat in an effort to correct for wear or distortion.

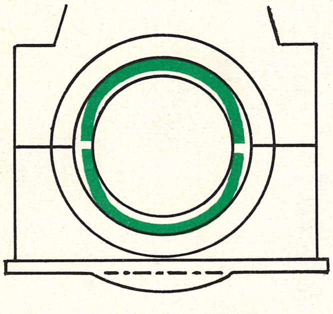
This matter of heat dissipation is one reason for bearing "crush." Crush means that the two halves of the bearing shell extend a few thousandths beyond the bearing seat bore as shown in exaggerated form in Fig. 15-16. When the bearing cap nuts are drawn down to the specified degree of tightness, the shell is thus forced to seat solidly and intimately in the bearing seats.

Another reason for crush is to make sure the bearing remains round. If it were not tightly held on the edge it might distort as shown in exaggerated form in Fig. 15-17, enough to allow the edges to touch the journal.

Still another reason for crush is to avoid any possible movement of the shell in the seats. If the shell should become slightly loose, it might oscillate in the seat and wear on the outside. This would interfere with both oil control and heat transfer. Any dirt between the shell and the bore will have the same effect. See Fig. 15-18.

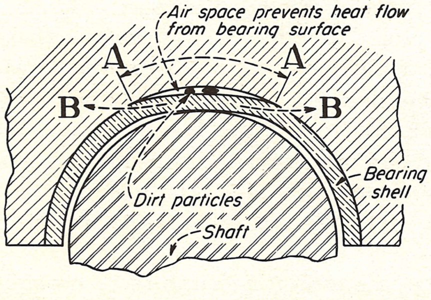


15-16. The edge of the bearing shells should extend slightly beyond the bearing seat in order that they will be forced into intimate contact with the seat when the cap is drawn up tight.



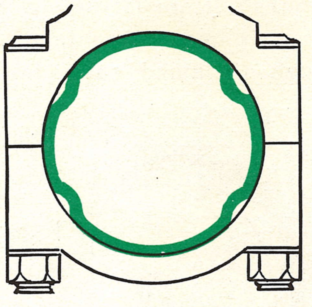
15-17. Lack of proper crush in bearing installation may permit the edges of the bearing to curl in toward the shaft.

This bearing crush must always be there and therefore the edges of the shell should not be dressed down flush with the bearing seats. Of course, the amount of crush must not be excessive. If it were, the shell would be distorted when the cap is drawn down and the bearing would be deformed as shown in Fig. 15-19.



15-18. Dirt between bearing shell and bore creates a dry spot on the bearing surface as well as hindering heat flow.

The amount of crush is only .001 or .002 in., and is finished to dimension the same as the bore and outside diameter. These shells are extremely accurate as they come from the manufacturer, and must be handled with care. They should be purchased to the precise size required, and inserted with no alteration or fitting.

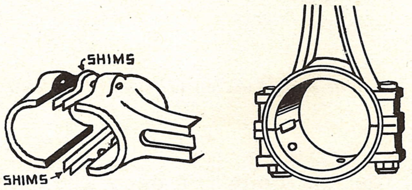


15-19. An excessive crush will of course cause the bearing to buckle when the cap is drawn down tight.

INTEGRAL BEARING ADJUSTMENT

When bearings of the integral type require adjustment it can be done at the bearing cap. The result will probably be a bearing that is out-of-round, but an engine lubricated by the splash method can operate satisfactorily with a slightly oval bearing on a round shaft. A pressure fed bearing uses a controlled volume of oil and must be round.

An adjustable bearing is usually provided with thin shims on each side. See Fig. 15-20. These shims are placed between the crankcase or rod when the bearing is poured, so we start out with a round bearing. Each time the bearing is adjusted for wear by the removal of these shims, it becomes more oval.

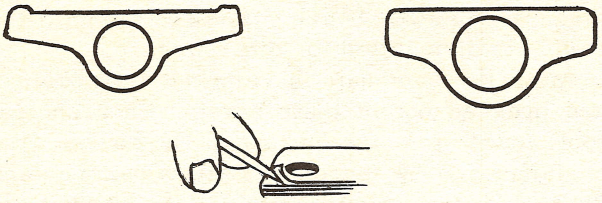


15-20. An adjustable connecting rod bearing provided with shims for adjusting clearance.

These shims are usually installed in several thicknesses; that is, .0005, .001, .002 in. etc., and the same quantity of each on both sides. Also the shims may be in laminated form; that is, a stack of shims each .0005 in. thick are soldered together at the edge to form a block. By peeling off as many layers as desired, the shim block is thus reduced in thickness. See Fig. 15-21.

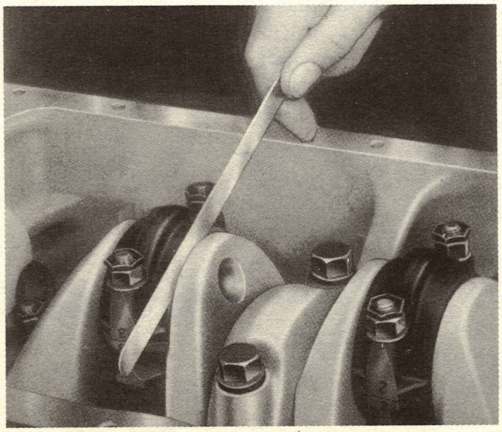
The usual adjustment procedure for main bearings, is to loosen all of the bearing caps and adjust one bearing at a time. Shims are removed in equal numbers of the same thickness from each side until a slight resistance to rotation of the shaft is felt. Shims of proper thickness to provide the clearance desired are then reinserted, and shaft rotation again checked.

If the bearing cap is warped so that the faces are not flat and level; or if the bearing is not provided with shims, the cap is dressed down. This is usually done by placing a sheet of emery paper on a face plate, or piece of plate glass and rubbing the cap face on the abrasive. Care must be exercised to avoid lapping the cap crooked when this method is used. A skilled machinist can dress the cap down by draw-filing, but an amateur will ruin the cap by filing it crooked.



15-21. Laminated shims may be of any shape desired and if equipped with a babbitt edge, this babbitt will need to be dressed down as the laminations are peeled off.

When all main bearings are adjusted properly and the caps drawn up tight, there should be little resistance toward rotation of the shaft. If there is resistance, one or more bearings are fitted too tightly, there is insufficient end clearance on the thrust bearing, the crankshaft is sprung or the bearings are not in correct alignment. If the engine is stiff after a bearing job, it should not be started until the cause of the stiffness is located and eliminated.



15-22. A feeler gauge can be used to check end clearance of connecting rod bearing.

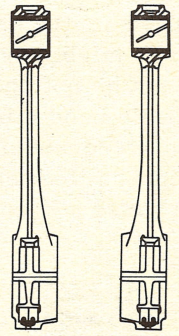
SIDE CLEARANCE

The connecting rod bearing must have some side clearance. If it has too much, the bearing may move sidewise and cause a knock. The clearance is measured by inserting a feeler gauge between the end of the bearing and the cheek of the crankshaft throw as shown in Fig. 15-22. While manufacturers' specifications vary somewhat, the usual clearance is .005 to .01 in. As there is no adjustment of the side clearance, excessive clearance requires replacement of the bearing.

CONNECTING ROD ALIGNMENT

In addition to the proper fit of the connecting rod bearing on the crankshaft, and the proper condition of the piston pin at the other end of the rod, we must consider the alignment of the rod itself.

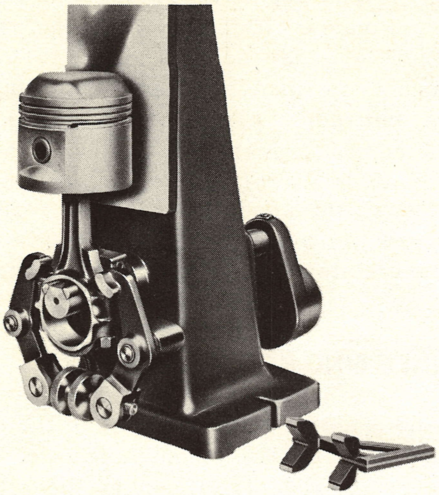
Most V-type and also opposed cylinder type engines have the cylinder blocks slightly offset from each other endwise to facilitate placement of the rod bearings on the crankshaft. It is also customary to offset the connecting rods, as shown in Fig. 15-23. This is done to place the power load as near to the main bearings as possible, which tends to reduce vibration of the crankshaft. While most connecting rods are all marked on the same side, it is something that should be watched during engine assembly.



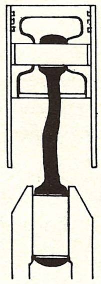
15-23. Connecting rods are often off-set with regard to the bearing surface, the short side of the off-set usually being nearest the main bearing.

Obviously, the piston pin and crankshaft journal must be parallel--not just approximately parallel, but precisely parallel. If the piston pin is not parallel with the crankshaft, every force on the piston will cause it to try to slide endwise on the piston pin. This will cause the piston to "slap" in the cylinder and create a knock or noise. The connecting rod and bearing will also have a tendency to knock.

Special equipment of suitable accuracy is available for checking the connecting rods as shown in Fig. 15-24. This type of equipment checks the rods for twist as well as bends. EVERY connecting rod should be checked for proper alignment just before it is installed in the engine. Many hard-to-locate noises in an engine originate in misalignment of the connecting rods.


15-24. *Typical connecting rod alignment fixture.*

Each rod should be checked again for location after it is installed in the engine. This for the reason that the rod might have a double bend in it, which would not be noticed on the alignment tester. Such a double bend might leave the piston pin parallel with the crankshaft, yet the upper end of the rod might be close enough to one of the piston bosses to cause a knock. See Fig. 15-25.

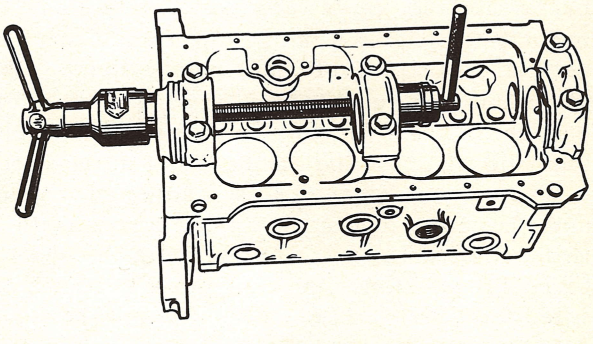

15-25. *Exaggerated illustration of a connecting rod with a double kink causing the upper end of the rod to ride against the piston boss.*

CAMSHAFT BEARINGS

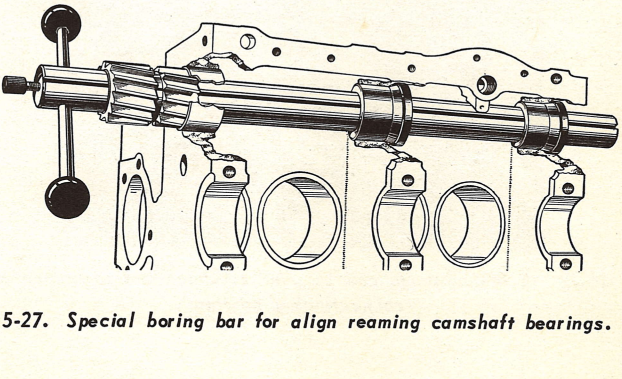
Camshafts sometimes bear directly in the metal of the crankcase as previously explained, but in most cases bearings are in the form of bronze bushings pressed into the crankcase. These bushings are not adjustable for wear, and are replaced when worn. The degree of wear dictating replacement is more a matter of their oil clearance than any tendency toward noise. If seriously worn, they may create noise and vibration in the timing gears and valve operation train.

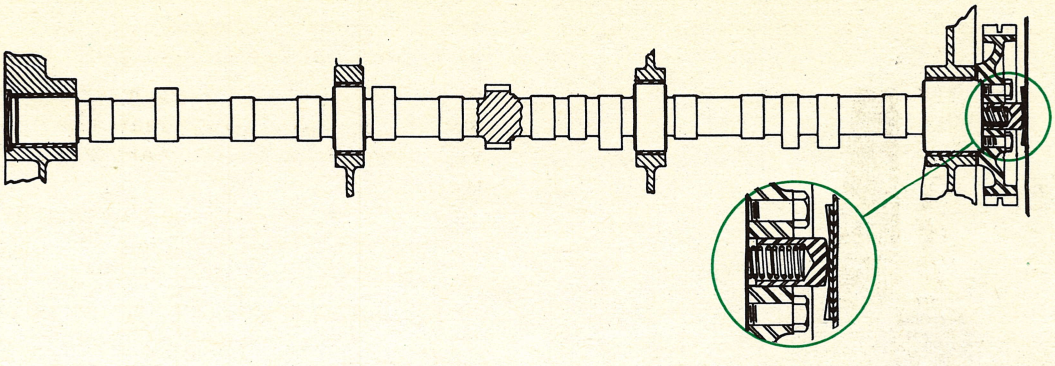
In order to replace the camshaft bearings, the camshaft must be removed. This involves removal of the valves and operating mechanism, or else raising and holding the valve lifters up off the camshaft against the tension of the valve springs. Actually it is seldom necessary to replace a camshaft bearing or bearings until the engine is dismantled for other work.

After the camshaft is removed the bearings are pressed out of their bores with a special tool made for the purpose. Of course, the bushings can be driven out with a hammer and drift, but the special tool will be needed for inserting the new bushings, and might as well be used for removal of the old ones. See Fig. 15-26.


15-26. *One type of special tool for removing and inserting camshaft bushings.*

New bushings are available in the proper outside diameter and standard as well as undersize inside diameter. If the camshaft has been undersized by regrinding worn journals, the bearings can be line reamed to any size desired by use of the proper equipment. See Fig. 15-27.


15-27. *Special boring bar for align reaming camshaft bearings.*



15-28. A spring loaded plunger prevents excessive endwise motion of this camshaft.

Before the new bushings are pressed into place, they are coated lightly on the outside with white lead. The white lead facilitates insertion by acting as a lubricant, and helps avoid distortion of the bushing. The oil holes in the bushings are lined up with the oil holes in the crankcase before pressure is applied, as the bushing cannot be turned after it starts in the bore.

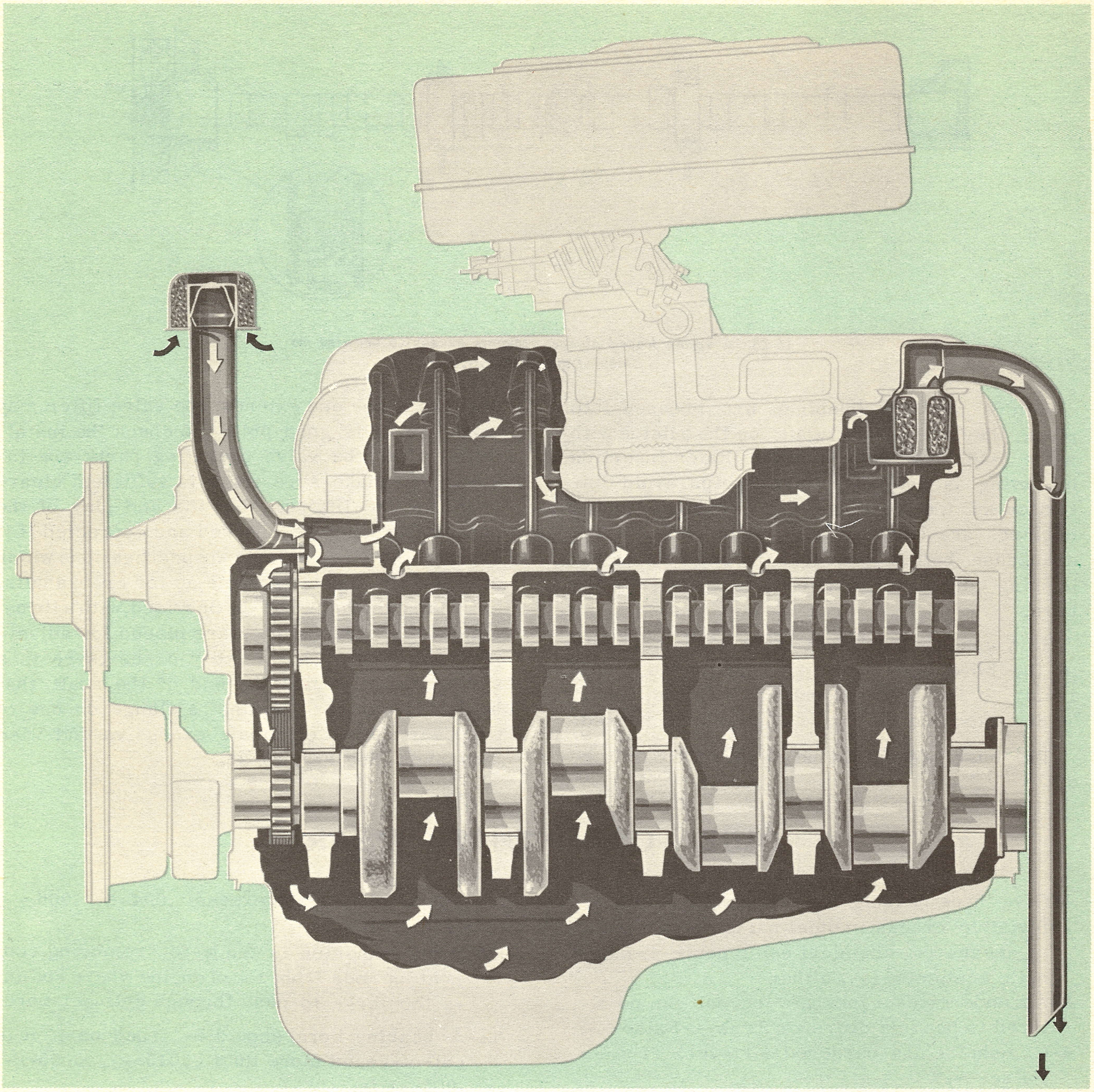
It is essential to start the bushing squarely in the bore and apply pressure steadily and evenly. If the bushing cocks in the bore, it will be distorted and the inside diameter decreased.

The bushings should be pushed fully into the bore as if one end extends, the valve lifter may strike it. It is good policy to check the installation after the valve operating parts are installed to make sure there is sufficient clearance for the lifters. Also the end-play of the camshaft should be checked and corrected if it exceeds the manufacturers' specifications which are usually about the same as for crankshafts.

Usually the camshaft is provided with a thrust plate under which shims are placed for adjustment of clearance. In other cases there is a spring and button at the end of the shaft, that holds the camshaft against a flange on one of the bearings to eliminate excessive end-wise movement. See Fig. 15-28.

QUIZ - CRANKSHAFT WEAR

1-Give three reasons for crankshaft wear.
2-Invisible cracks in steel parts may be found by means of: chemical equipment---, magnetic equipment---, either---.
3-An undersize crankshaft journal can be altered to become oversize. True---False---.
4-Camshafts are hardened all over. True--- False---.
5-Clearance between crankshaft and bearing in a splash lubricated engine may be: more---, the same---, less---, than in a pressure lubricated engine.
6-What happens if oil clearances are unequal in a pressure oiling system?
7-Name two ways of measuring bearing clearance.
8-In general, the diametral clearance in a small engine main bearing should be: .0005 to .001---, .001 to .0015---, .0015 to .002--- in.
9-In general, endwise clearance for crankshafts should not exceed: .004---, .006---, .008--- in.
10-What provision is made for removing connecting rods from top of engine where rod end is too large to pass through cylinder bore?
11-A bearing bore should be trued up if it is out-of-round more than: .0015---, .0025---, .005--- in.
12-Name two reasons for bearing crush.
13-In adjusting integral bearings, the same quantity of shims should be removed from each side. True--- False---.
14-Should the short side of the offset on the No. 1 connecting rod be toward the front---, or rear--- of the engine?
15-A piston pin can be properly fitted and parallel with the crankshaft and still cause a knock. True--- False---.
16-If a camshaft bushing is pressed in crookedly, the inside diameter will be: increased---, decreased---.

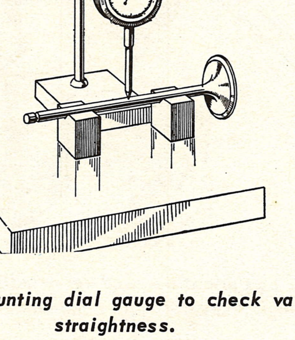


Side view of Ford V-8, 221 cu. in. engine, showing crankshaft and camshaft, also engine ventilation.

VALVE SERVICE

This text has previously emphasized that the condition of the valves has much to do with engine efficiency. We have also seen that poppet valves lead a hard life. It is not surprising that valve service is therefore a frequently performed operation in the service station.

Valve service was once a hand lapping procedure using an abrasive paste between the valve face and valve seat. This procedure was assumed to provide a gas tight valve, and little attention or thought was given to valve seat width, heat dissipation, concentricity of valve with seat, strength of valve springs, wear in valve guides and all the other things that require attention on the modern high speed, high compression engine.

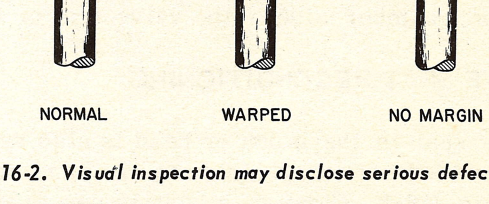


16-1. Method of mounting dial gauge to check valve stem for straightness.

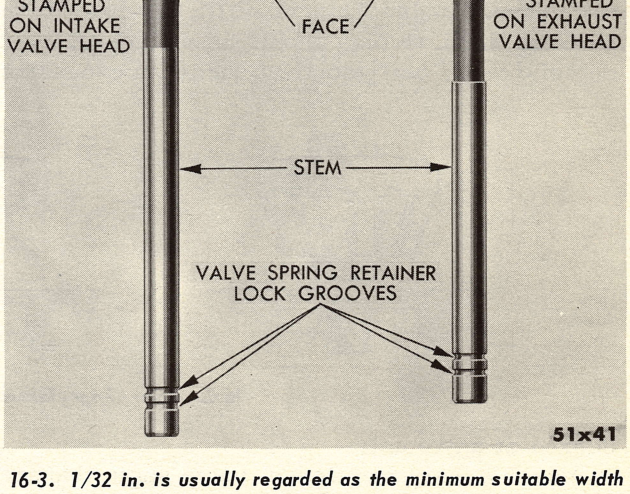
Modern "valve grinding" is a true grinding process rather than a lapping procedure. Every part of the operation is governed by careful measurement with accurate equipment. The first step after the valves are removed and cleaned, is to determine whether the valve can be reconditioned or whether it must be replaced. If the stem is scored, pitted, bent or worn more than .002 in. it is usually discarded.

Visual inspection will disclose obvious damage. The stem diameter can be checked for wear with a micrometer. A dial gauge and V-blocks can be used to check the stem for straightness. See Fig. 16-1.

Visual inspection may also disclose a seriously warped valve head, a split valve face, or a lack of margin. See Fig. 16-2. If the face is

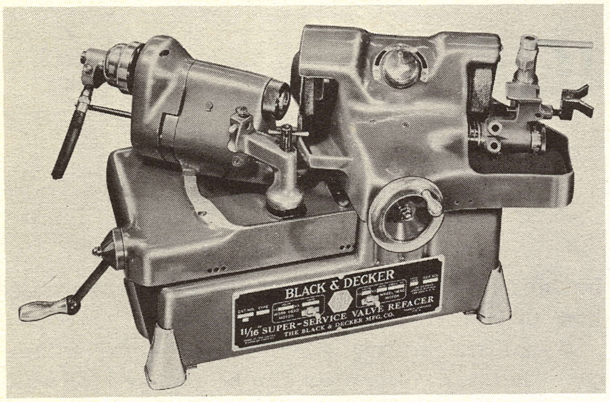


16-2. Visual inspection may disclose serious defects.


"IN" STAMPED ON INTAKE VALVE HEAD
MARGIN
FACE
"EX" STAMPED ON EXHAUST VALVE HEAD
STEM
VALVE SPRING RETAINER LOCK GROOVES
51x41

16-3. 1/32 in. is usually regarded as the minimum suitable width for the valve margin.

burned, badly warped or worn to a thin margin the valve is discarded. See Fig. 16-3. If the valve appears to be in good condition, it is placed in a special grinding machine known as a valve refacer, and a new surface is ground on the face at the proper angle with and concentric with the stem. See Fig. 16-4.

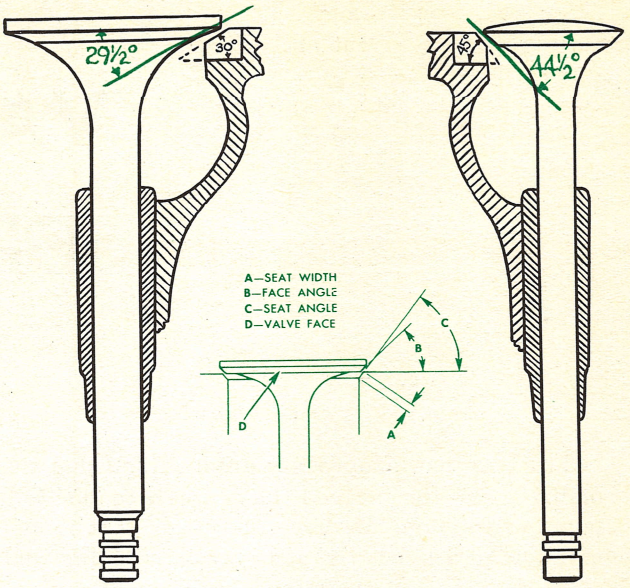

BLACK & DECKER
11/16" SUPER-SERVICE VALVE REFACER
THE BLACK & DECKER MFG. CO.

16-4. A typical special machine designed for grinding valves accurately.

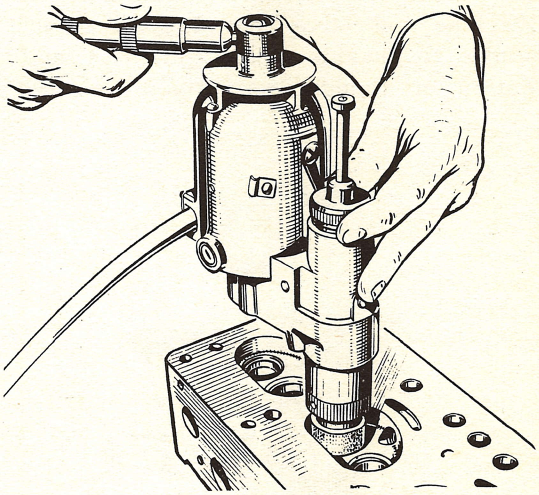
Most valve faces are cut at an angle of 45 deg. with the stem. An angle of 30 deg. is also used. In either case a slight interference angle--about 1/2 to 1 deg. -- may be cut on either the valve face or valve seat, to improve the seating ability. See Fig. 16-5. In either case this angle must be on the stem side rather than on the combustion chamber side of the valve seat or face.

VALVE SEAT RECONDITIONING

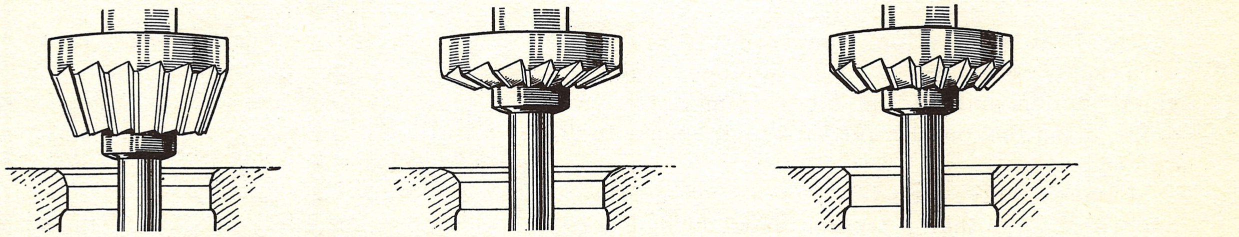
The seat in the block or head is also resurfaced with the aid of special reamers or grinders. See Fig. 16-6. First of all, it is necessary to position the tool so it will be located to cut the seat concentric with the valve stem guide and at the proper angle. This is difficult to do if the guide is worn. Guides should be replaced if worn out-of-round, bell-mouthed, or to an excessive degree at any point.



*16-5. In some cases a slight interference angle is cut on the **UNDER** side of the valve seat or face as shown here.*



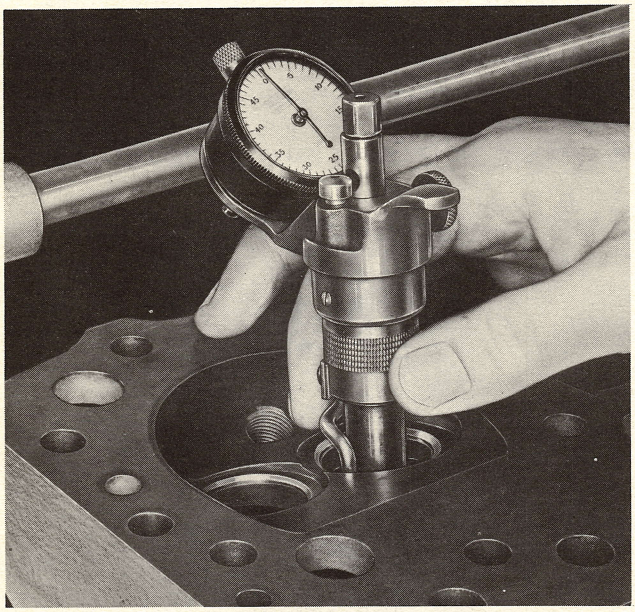
16-6. Special equipment as used for grinding valve seats. Such equipment is essential where hardened seats are used.



16-7. A set of special reamers for narrowing valve seats.

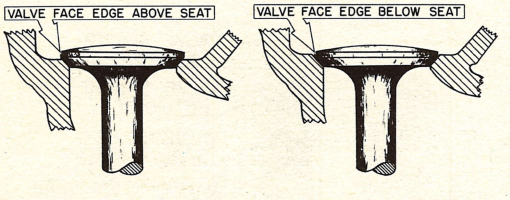
As previously mentioned, valve seats that are too narrow will not dissipate the heat properly, and if too wide will encourage carbon to adhere to them. In the absence of factory specifications, a seat 1/16 in. wide is usually satisfactory. If the seat is wider than this, the first operation will be to narrow the seat by cutting an acute angle under the seat, and an obtuse angle above the seat. This is done with special reamers or grinders made for the purpose. See Fig. 16-7.

After the seat is sufficiently narrowed, the seat surface is then cut or ground to the proper angle. This cutting or grinding must result in a smooth, true surface if the valve is to be gas-tight. It cannot be true, if the seat is not concentric with the valve stem. A method of testing with a dial gauge is shown in Fig. 16-8. The seat should be concentric with the guide within .001 in.



16-8. A specially mounted dial gauge is used to check the concentricity of the valve seat with the valve guide.

Sometimes the valve seat becomes so enlarged that the valve head sinks into the seat. See Fig. 16-9. In this case, the remedy is to install oversize valves or install valve seat inserts.



NORMAL VALVE SEAT

VALVE SEAT TOO LARGE AND DEEP

16-9. Oversize valves can be used in cases where the block or head cannot be bored out for inserted valve seats.

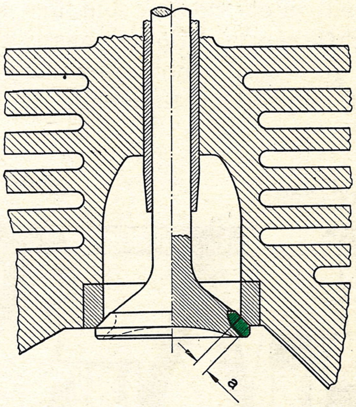
VALVE SEAT INSERTS

Hardened valve seat inserts are ordinarily used in air cooled automobile engines having aluminum cylinder heads. In some cases the exhaust valves will also have a heat resistant face attached. See Fig. 16-10. Valve seat inserts are also used in many engines having cast iron blocks or heads.

If the insert is badly worn or burned, it may be easier to replace the insert than to try to recondition it. These seats are made of hard, heat-resisting metal, and cannot be reamed like an integral seat in a cast iron head or block. The inserts are refaced by grinding with special grinders.

If the seat is of the screw-in type, it is a simple matter to unscrew the old seat and screw in the new one. The seating surface is of course ground after the insert is in place. The pressed-in, or shrunk-in inserts are usually held tightly in place by rolling or peening the metal around the edge of the insert, after it is in place.

As it is sometimes difficult to clean up the peening enough to allow the insert to be pulled, the inserts are usually broken for removal. Whether the old insert is pulled or broken out, it is essential that the hole for the insert be round and true. If the insert does not bottom fully in the hole, or if it does not fit tightly all around the hole, there will be poor heat transfer from the insert to the head or block, and the insert will run hotter than it should.



16-10. The Volkswagen engine has a special heat resistant alloy valve face.

For this reason, the inserts are usually of such size as to provide an "interference fit;" that is, the insert is one or two thousandths larger in diameter than the hole into which it is to be installed. In this case, to avoid the stresses imposed in pressing them in place, the inserts are often shrunk for insertion. This is often done at the factory by immersing the insert in liquid air for a short period.

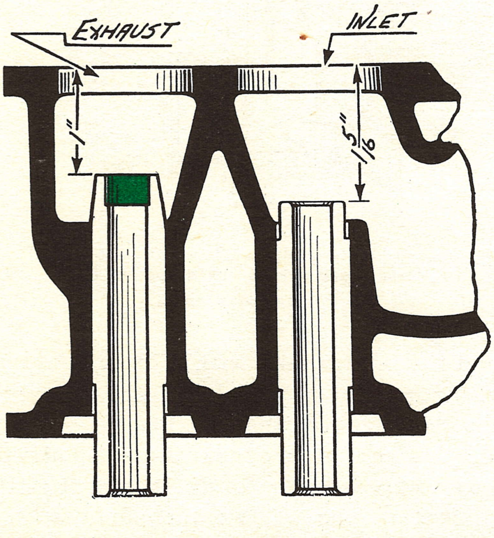
For service installation, the inserts may be placed in a deep freeze for a few hours, or packed in dry ice for a few minutes. Either of these procedures will shrink them sufficiently for easy insertion. When so frozen, the inserts must be handled carefully and quickly, as they are quite brittle and will crack or split easily.

After insertion, the metal around the insert may be lightly rolled or peened over the top outside edge of the insert, to help hold it firmly in place. The final step is to grind the seat for the valve on the insert true with the valve guide.

VALVE STEM GUIDES

Most engines have separate valve guides of the press-in type, but some engines are built with the valve stem in direct contact with a hole bored in the cylinder block or head. Heat dissipation is better where guides are not used, but wear in the guides means boring the holes out larger, and fitting new valves with oversize stems. In most cases the separate guides are made of cast iron, but bronze is used in some cases, because of the superior wearing characteristics, and more rapid heat dissipating ability.

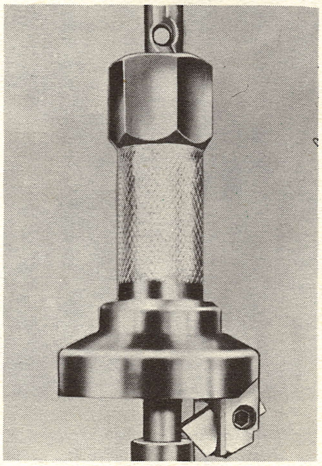
Press-in guides are often identical for the exhaust and inlet valves, but are sometimes installed differently. In other cases the exhaust and inlet guides are not interchangeable. See Fig. 16-11. In still another case the guides are identical, but the inlet guides are installed upside down from the exhaust guides. Some exhaust guides are cut off shorter in the port opening, and others are counterbored in the port end, to reduce the tendency for carbon to accumulate in the guide.



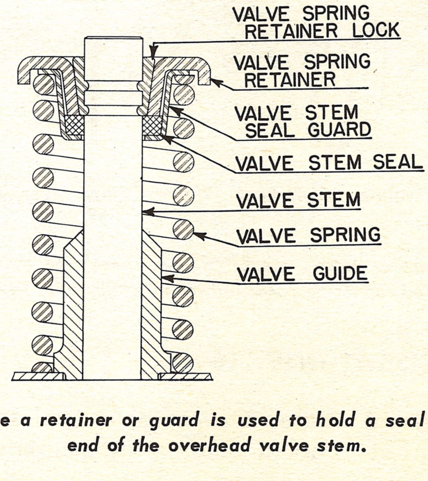
16-11. These valve guides are not identical and the exhaust extends farther into the port than the inlet. Note the counterbore in the exhaust guide.

Carbon does accumulate in the guide bore and on the stem of exhaust valves, and causes them to stick partly open or to slow down in action. The tendency for carbon to accumulate increases as the valve stem and guide wear, because more hot gas blows by between valve stem and guide. Wear on the intake stem and guide is equally undesirable because such wear permits air to be drawn in through the clearance, and dilute the air and gasoline mixture. Under such conditions it is impossible to obtain a satisfactory carburetor adjustment.

Furthermore, oil from the valve chamber may be sucked in between valve and guide, to increase oil consumption and carbon up the engine. This oil leakage is sometimes pronounced on overhead valve engines, as oil is pumped up on the valve operating rocker arms. To discourage this tendency, a special cutter is



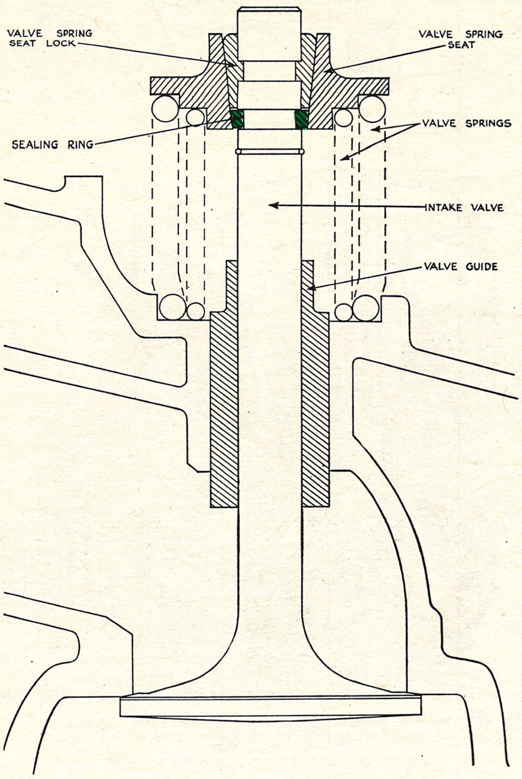
16-12. Special tool for cutting taper on end of valve guide to discourage oil from accumulating on top end of overhead valve guide.



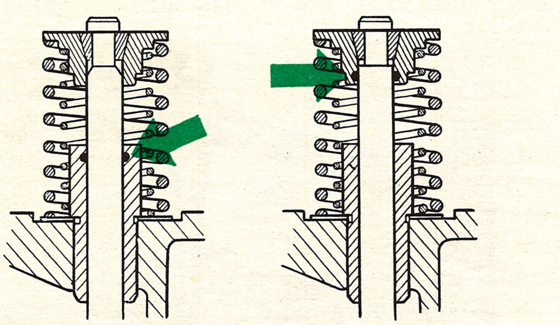
16-13. Here a retainer or guard is used to hold a seal near the end of the overhead valve stem.

available to cut a bevel on the end of untapered valve guides. See Fig. 16-12.

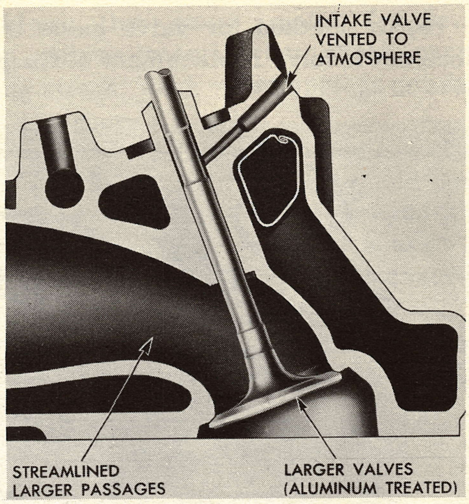
It is customary to place seals either on the valve stem or in the guide on overhead valve engines, to exclude excess oil. Several types are shown in Figs. 16-13, 16-14 and 16-15. One manufacturer vents the valve guide to the atmosphere to break up this suction as shown in Fig. 16-16.


VALVE SPRING SEAT LOCK
VALVE SPRING SEAT
SEALING RING
VALVE SPRINGS
INTAKE VALVE
VALVE GUIDE

16-14. *In this case a seal is placed in a groove in the overhead valve stem.*

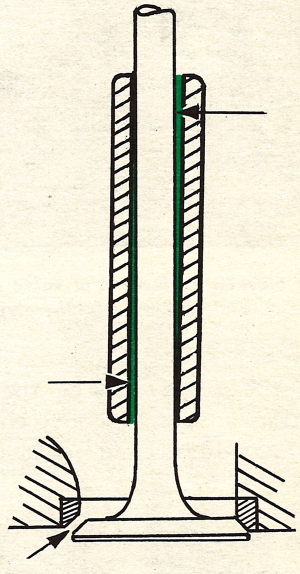


16-15. *Two methods of using "O-ring" seals on overhead valves.*


INTAKE VALVE VENTED TO ATMOSPHERE
STREAMLINED LARGER PASSAGES
LARGER VALVES (ALUMINUM TREATED)

16-16. *Note reduction in part of valve stem diameter at vent opening on this Pontiac inlet valve design.*

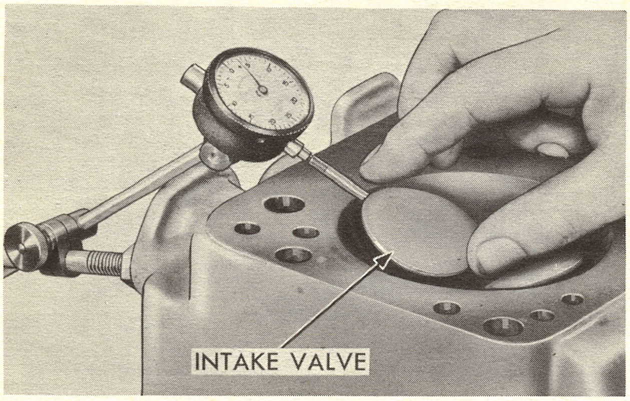
Another undesirable result of excessive valve guide wear is to permit the valve to wobble enough to cause it to ride to one side of the valve seat as shown in Fig. 16-17. Quite naturally, this interferes with proper seating and sealing of the valve and also promotes wear. It is customary to replace the valve guides or valves, or both, whenever more than .005 in. clearance for small valves or .006 in. for large valves exists between valve stem and guide. One method of measuring clearance is shown in Fig. 16-18.



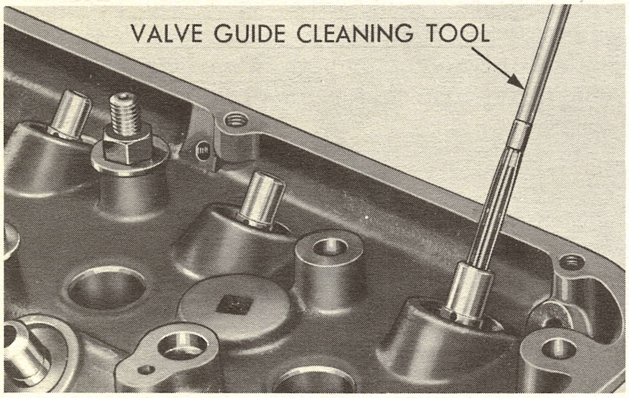
16-17. *Looseness in the valve guide permits the valve to wobble and cause undue wear of valve and seat.*

Before any measurement is made, the valve stem must be cleaned and polished, and the valve stem guide thoroughly cleaned of carbon deposits. Special tools are made for cleaning carbon out of valve guides as shown in Fig. 16-19. The measurement for clearance should be made with the valve slightly off the seat as shown in Fig. 16-18. The valve spring must also be removed while making the measurement.

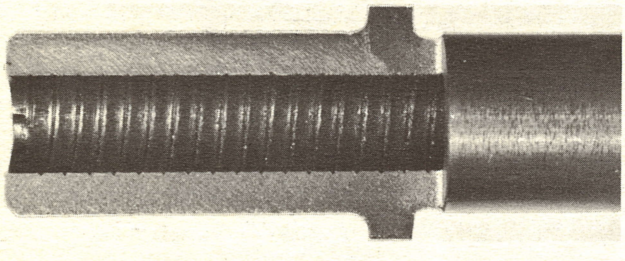
One repair method for valve guide troubles that does not involve replacement of the guides, is to upset the metal inside the valve guide bore by rolling a spiral groove through it. See Fig. 16-20. The idea here is to decrease the inside diameter slightly, and at the same time to form a continuous pocket for oil to gather and act as a seal. A special tool is made for this purpose.



***16-18.* When measuring the clearance between valve and guide, the valve must be off the seat as shown here.**

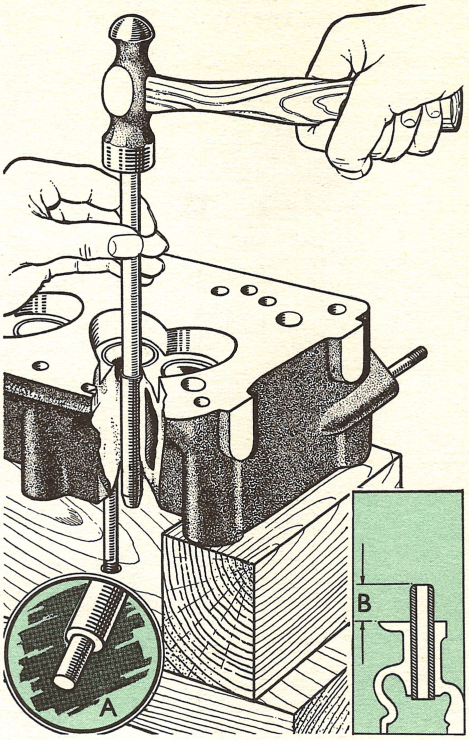


***16-19.* Method of cleaning carbon out of valve guides with special tool made for the purpose.**

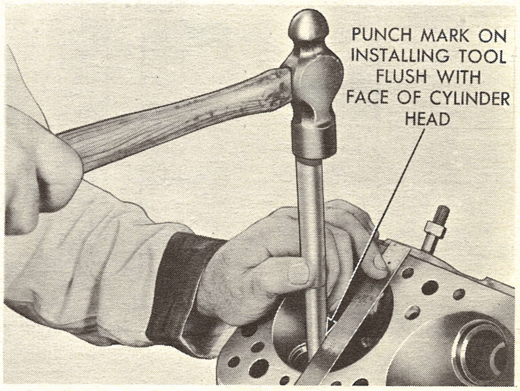


***16-20.* Valve guide partially cut away to show spiral groove made by special tool.**

When valve guides of the press-in type are replaced, it is important to have them positioned properly in the block or head. See Fig. 16-21. The car manufacturer specifies the proper position with regard to some accessible surface, from which measurement can be made. An example of this is shown in Fig. 16-22.



***16-21.* A is the end of the pilot driver used in removing and replacing the valve guide. B is the dimension specified by the manufacturer.**

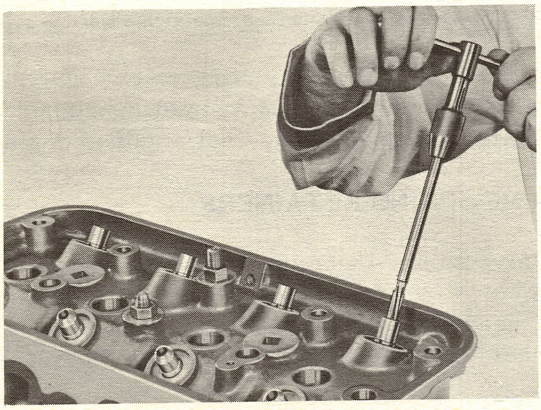


***16-22.* Valve guides must be accurately positioned in the head or block in accordance with the manufacturers' specifications.**

In some cases where an unusual amount of trouble is experienced with exhaust valves sticking due to rapid accumulation of carbon, it has been found helpful to cut off the end of the exhaust guide. This is often done with a drill ground to a flat angle on the end. The guide is cut down even with the opening in the port in which the guide is located.

After the guides are pressed in place, it is usually necessary to ream them to proper size, and provide clearance for heat expansion of the valve stem. Special reamers are made for this purpose as shown in Fig. 16-23. This operation must be performed carefully so that the hole will be straight and true with a good surface.

Exhaust valve stems will require more clearance in the guides than inlet valves. In the absence of specific instructions, it is customary to fit intake valves with .001-.003 in. clearance, and exhaust valves with .002 -.004 in. clearance, depending upon the size of the valve stem.



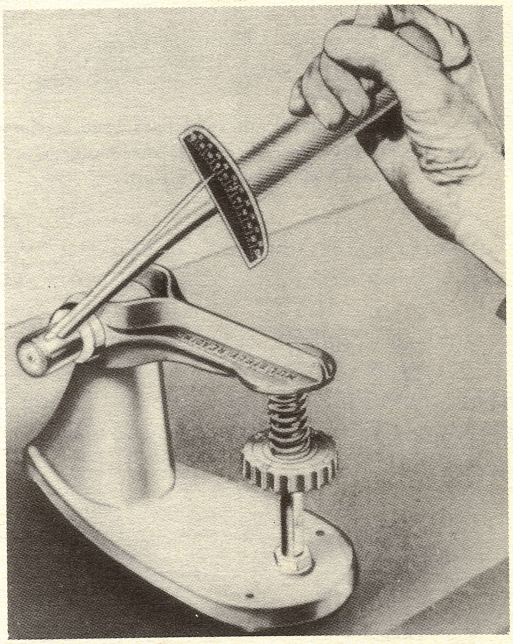
16-23. *Special reamers make it possible to ream valve guides to the accurate dimensions required.*

VALVE SPRINGS

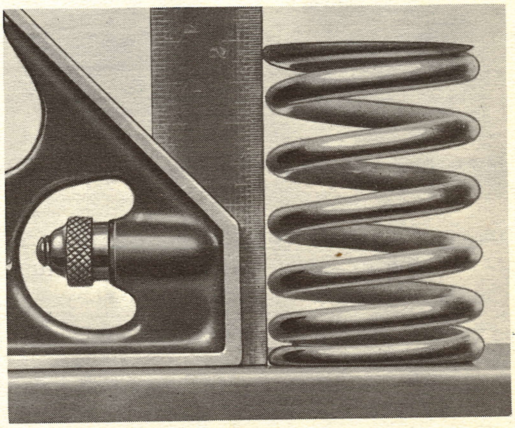
Valve springs seldom receive the attention they deserve. They are an exceedingly important part of the engine, and have much to do with the engine performance. They are seldom replaced unless broken, yet should be replaced when they are not up to specifications. They work hard, being subjected to millions of cycles of high speed operation, and all of it under shock conditions.

The valves are opened with lightning-like speed by the action of the cam and the spring is expected to close the valve just as fast as it is opened. The valve lifter is thus kept in contact with the cam. If the spring is weak and does not hold the lifter in contact with the cam, noise will be created and the valve, spring, lifter and cam will be subjected to hammer-like blows that cause metal fatigue. Many broken valves result from shock caused by sticking stems, weak valve springs or excessive tappet clearance.

The car manufacturer provides specifications on the free length of the spring, and the pressure in pounds that the spring should exert when it is compressed to a measured length. Special tools are available for measuring the length and strength of the spring. See Fig. 16-24.



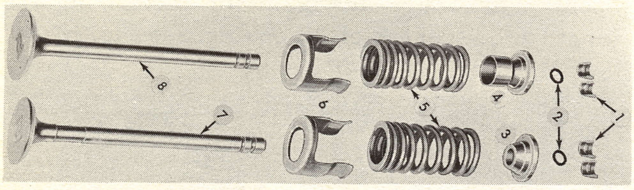
16-24. *Typical tool for measuring valve spring length and strength.*



16-25. *Valve springs should be square on each end and of the proper length.*

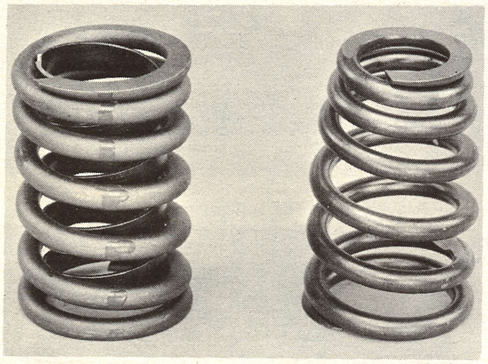
Valve springs are simple, inexpensive coil wire springs, and should not be expected to last forever.

They should be square on each end, as otherwise they will have a tendency to pull the valve stem to one side, and cause undue wear on the valve stem and guide. They can be checked for squareness and free length as shown in Fig. 16-25. When the coils of the spring are wound closer together at one end than at the other, the close coils are to be placed next to the engine block or head. See Fig. 16-26. This uneven coiling is done to lessen the tendency of the spring to vibrate or "flutter" at high speeds.



16-26. Metal cups or dampers are sometimes used on the closely coiled ends of the valve springs next to the engine block to reduce high speed valve flutter.

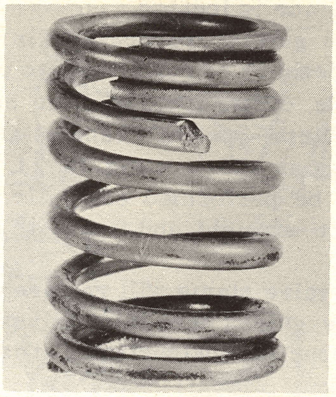
Another method of reducing flutter is to install dampers as shown in Fig. 16-26. Still another method is to taper the spring or to use two lighter springs, one within the other, instead of one heavy spring. See Fig. 16-27. The two springs are usually wound in opposite directions. Whatever the construction used, it is important to check the springs whenever they are out, and replace them whenever they are not up to specifications.



16-27. Dual coil spring at left, tapered spring at right.

Periodic replacement is also good to avoid unexpected failure. Valve springs often become "etched" when the valve chamber is subject to corrosive vapors. Some valve chambers are not well ventilated and steam or moisture containing acids formed from combustion will collect and cause flecks of rust to form on the valve springs. This etching is liable to cause the spring to break. See Fig. 16-28.

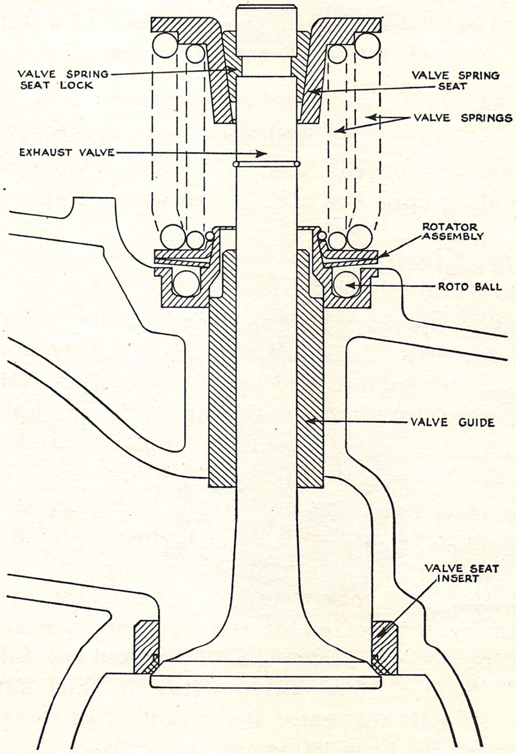
This corrosive action is similar to the corrosion that causes pits and rust to eat into valve stems. On the valve stems it means wear, but a broken valve spring on an overhead valve engine may permit the valve to drop into the cylinder and damage or ruin a piston, or cylinder head. New valve springs are then sometimes insurance (and cheap insurance) against a ruined engine.



16-28. Although not heavily etched, this spring broke in service.

VALVE SPRING RETAINERS

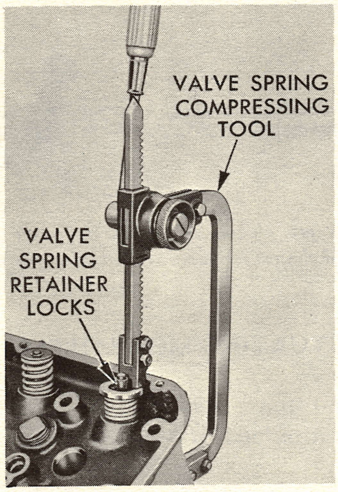
Valve spring locks or "keepers" are usually a pair of C-shaped washers that fit into a slot cut near the end of the valve stem. A cupped washer called a retainer fits over these semi-



16-29. Typical tapered C valve spring seat lock as installed on valve assembly.

circular keys, and the tension of the spring bearing on the retainers holds the locks in place. See Fig. 16-29. Other methods are also used. Slots cut near the end of the stem and a key or pin pushed through the slot, threads cut on the end of the stem for a nut and lock nut, etc.

Removal is accomplished by holding the valve stationary while the spring is compressed enough to allow the retainer to be raised from the locks. See Fig. 16-30. The locks are then removed and the valve spring released. This allows the valve to be removed, and then the spring and retainer can be removed. Valves should never be mixed up when removed, unless it is known that new valves or guides are to be installed. The valves should always be replaced in the same guide from which they were removed.

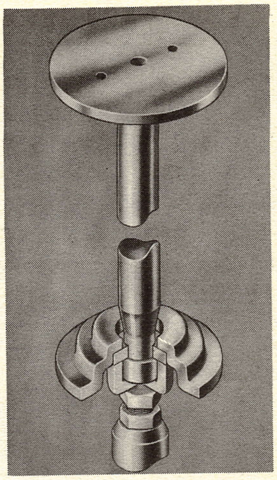

VALVE SPRING COMPRESSING TOOL
VALVE SPRING RETAINER LOCKS

16-30. Compressing the valve spring allows the retainer locks to be removed which frees the valve and the spring for removal.

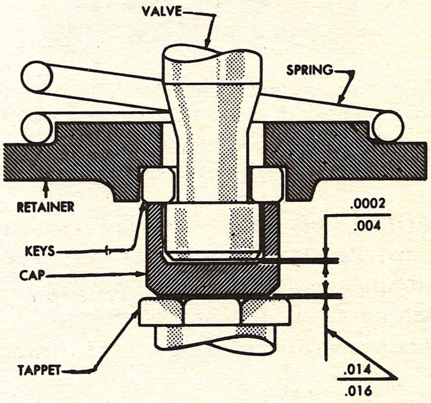
VALVE ROTATORS

Some retainers are more complicated and are intended to permit or encourage the valve to rotate slightly with regard to the seat. Some of these are called "free valves" and the purpose is to provide a longer lasting seal between valve and valve seat. Rotation of the valve will discourage the formation of carbon deposits, and help prevent valve warpage.

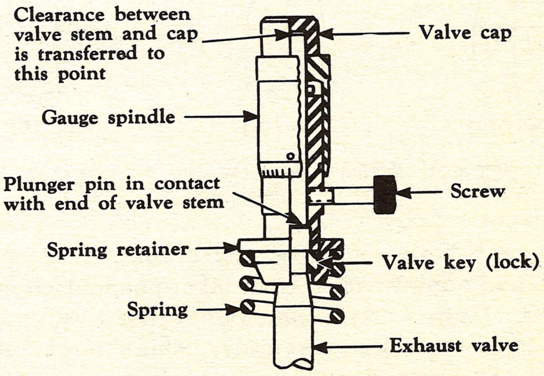
Some of these free valve devices release the valve from the valve spring tension at one point in the cycle of operation, so that it is free to rotate slightly. One type is illustrated in Fig. 16-31. With this type it is important to maintain the clearances between stem and cup and between cup and retainer within specified limits. See Fig. 16-32. If the clearance between stem end and cap is too little, the end of the valve stem is ground off as needed. If the clearance is too great, the skirt of the cap is ground off as required. A special tool is available for measuring the clearance accurately. See Fig. 16-33.



16-31. Construction of free valve device.

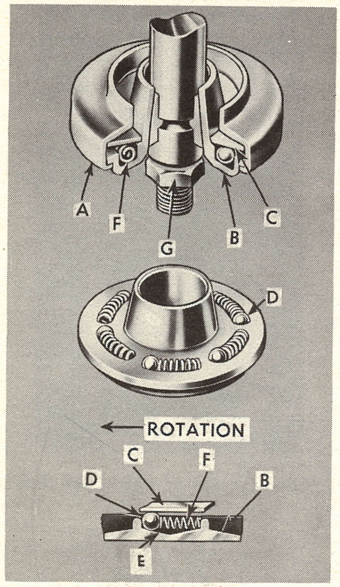

VALVE
SPRING
RETAINER
.0002
.004
KEYS
CAP
TAPPET
.014
.016

16-32. With this free valve device, it is important to maintain the clearance between the end of the valve and the cap.


Clearance between valve stem and cap is transferred to this point
Valve cap
Gauge spindle
Plunger pin in contact with end of valve stem
Screw
Spring retainer
Valve key (lock)
Spring
Exhaust valve

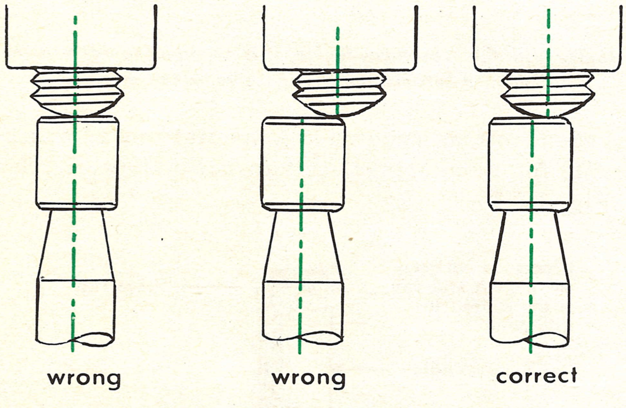
16-33. Special gauge for measuring free valve clearance.

Other devices are known as valve rotators, and impart a positive rotational effort to the valve once during each cycle of operation. One such device is illustrated in Fig. 16-34. Also see Fig. 16-29.



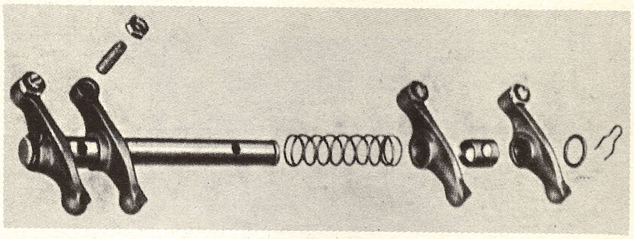
16-34. In this case, positive rotation of the valve is caused by the inclines down which the balls roll when pressure is applied. A-housing, B-retainer, C-cupped washer, D-balls, E-ramp, F-spring, G-valve lifter.

Regardless of the type device used to provide or permit rotation of the valves, there appears to be no question about their ability to assist in maintaining a satisfactory seal between valve and seat. They are also claimed to minimize sticking and wear between guide and stem. Other than cost and complication, the only apparent objection to them is the slightly increased weight of the reciprocating assembly, which might encourage a tendency toward flutter in an extremely high speed engine.



16-35. Method of obtaining valve rotation on Volkswagen engine.

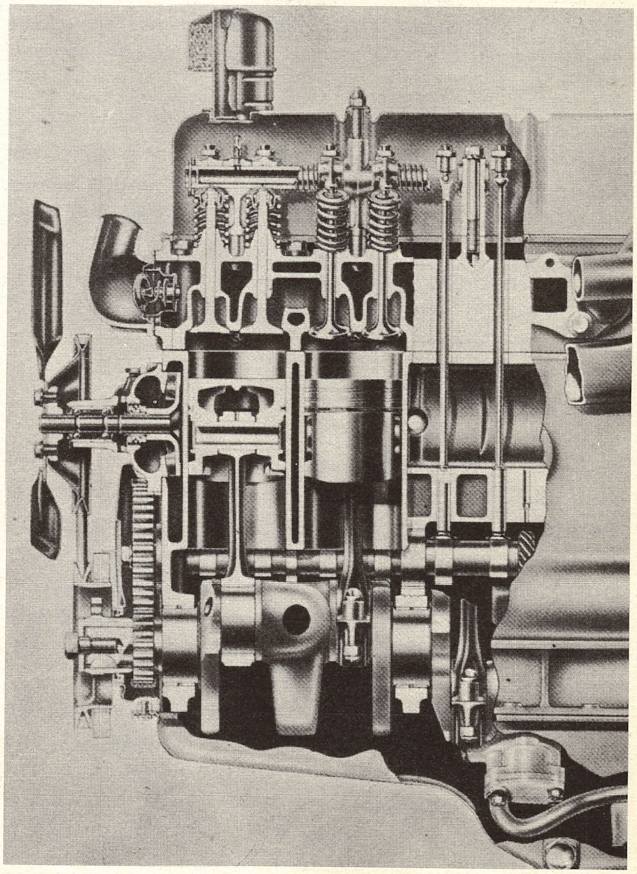
The German Volkswagen engine design contemplates slight rotation of the valves without adding any extra parts. This is done by adjusting the valve rocker arms to contact the valve stems slightly off center. The correct amount of offset is indicated in Fig. 16-35. This adjustment is accomplished by adding or removing spacers on either side of the rocker arms, as required to move the rocker arm lengthwise as needed. See Fig. 16-36.



16-36. Spacers are placed on the valve rocker shaft on either side of the rocker arms to obtain proper offset.

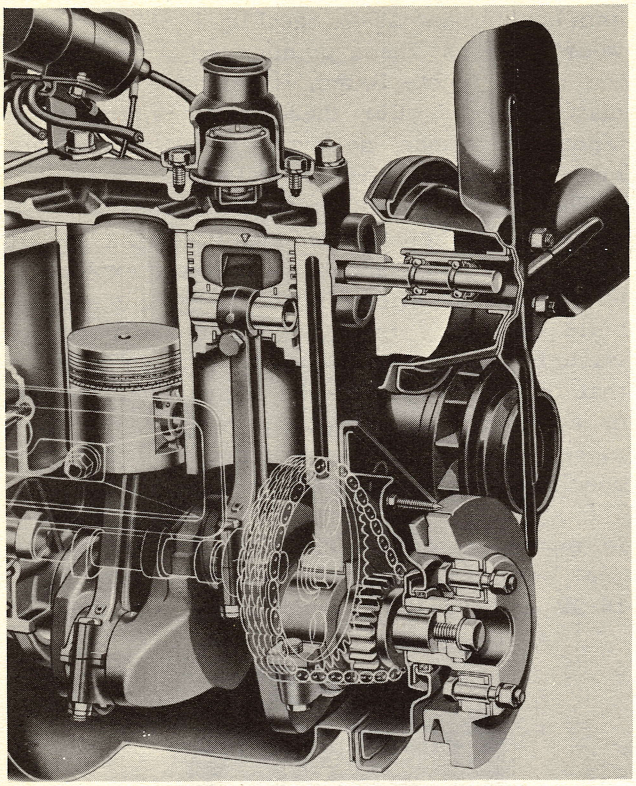
VALVE ACTUATING MECHANISMS

It is customary in U.S.A. built engines to mesh the camshaft drive gear directly with the



16-37. Location of gear driven camshaft on an overhead valve engine.

crankshaft gear, or in the case of chain drive to locate the sprockets near each other. See Figs. 16-37 and 16-38. Several European engines have the camshaft mounted about half way up the cylinder block, which requires an idler gear between camshaft gear and crankshaft gear, or else the use of a long drive chain.



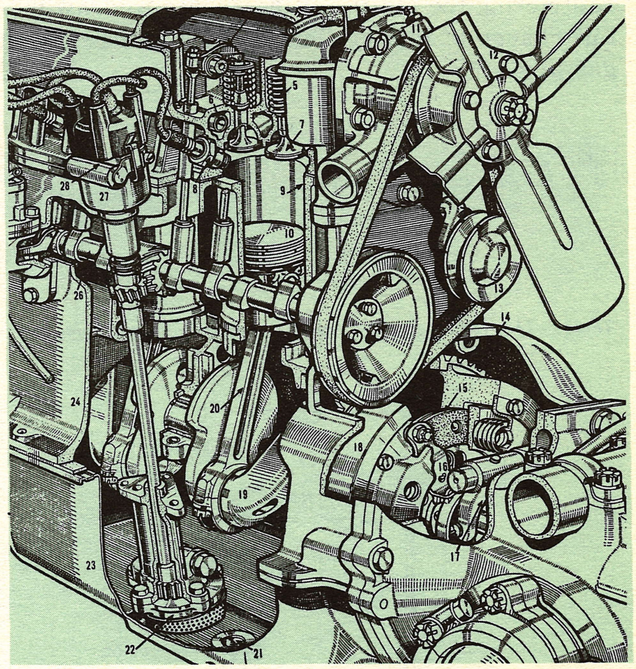
16-38. Location of chain driven camshaft as used on an L head engine.

The advantage of this design is to reduce the weight of the reciprocating push rods, and to avoid springing or bending of the push rods at high speed. The disadvantage is the extra gear or extra chain length. The French Renault construction is shown in Fig. 16-39.

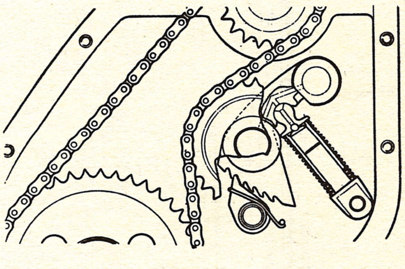
Where long chains are used to operate camshafts, the problem of slack or lost motion presents itself. Valve timing must be precise. Sloppy motion cannot be tolerated. Several devices have been tried to control this, and one of the most interesting is an automatic hydraulic chain tightener as used on the English Rover. This design is shown in Fig. 16-40. Engine oil pressure is used in the hydraulic cylinder.

WORN VALVE MECHANISM

Of course the camshaft and camshaft drive are only part of the mechanism used to operate the valves. To continue the study of valve action and timing, we must consider parts such as lifters, push rods, rocker arms, etc. Each one of these parts has something to do with valve timing. It is well to consider at this time that many minor faults may equal a major fault. In other words, a little wear at many points in the valve train may be equal in effect to considerable wear at one point.



16-39. Renault places this camshaft half way up the cylinder block which requires an idler gear between the crankshaft and camshaft gears.

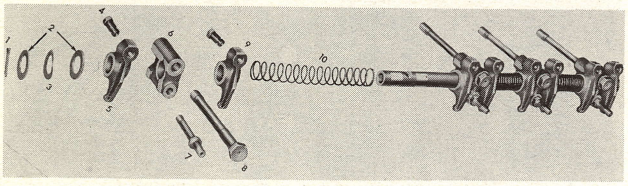


16-40. Automatic hydraulic timing chain tensioner, or adjuster used on Rover engine.

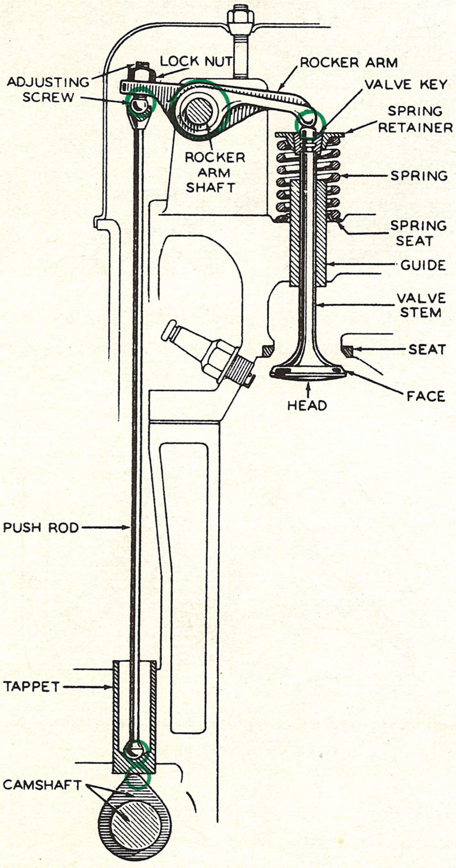
For example, suppose there is .005 in. excess wear between the gear teeth. This will allow the valves to open late and close early. Add to this another .005 excess wear in the camshaft bearings, which will reduce the valve lift as well as increase the late opening and early closing of the valves. Add another .005 worn from the cam contour which also changes the valve lift or timing or both. Now on top of all this, add another

.005 excess wear between the lifter and guide. This results in the lifter moving sidewise in the guide, before it starts to lift the valve.

Obviously all this cumulative wear will interfere with efficient operation of the engine. Such conditions are often further aggravated by careless adjustment of the valve tappets. Many mechanics who do not understand valve action, adjust the tappets with too much clearance to make sure there is no possibility of the valve holding open. They do not realize that they are restricting the ability of the engine to draw in a full charge of mixture, and dispose of the exhaust gas properly.



16-41. *The rocker shaft assembly consists of multiple parts.*

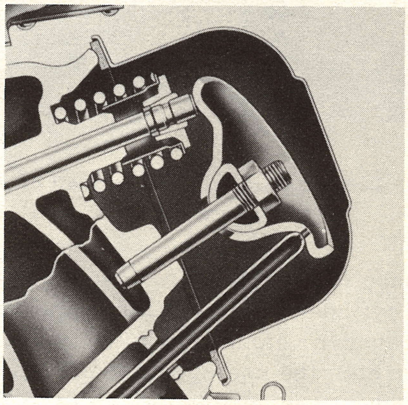


16-42. *There are many points of wear in the valve operating train: the valve cam contour, the lower face of the valve lifter, the sides of the lifter and guide, both ends of the push rod and the sockets in which they fit, the rocker arm shaft and bushings, the rocker arm end contacting the valve stem. A little wear at each of these points adds up to a lot of wear in the train.*

The foregoing example does not embrace the condition in an overhead valve engine which can become much worse. Here we have additional wearing parts such as both ends of the rocker arm operating rod, the rocker arm, rocker arm bushing and shaft. See Fig. 16-41. If excess wear exists at these points, and it is added to the other points listed, it becomes a serious matter indeed. For these reasons, the valve tappet clearance on overhead valve engines must be more carefully adjusted.

The engine manufacturer furnishes precise valve tappet clearance specifications in all cases, and these should be followed explicitly. Otherwise, the efforts of the design engineer to build efficiency into the engine are partially wasted. These specifications are so precise that they state whether the engine should be hot or cold when the adjustment is made. Furthermore, some manufacturers provide a different specification for checking the valve timing.

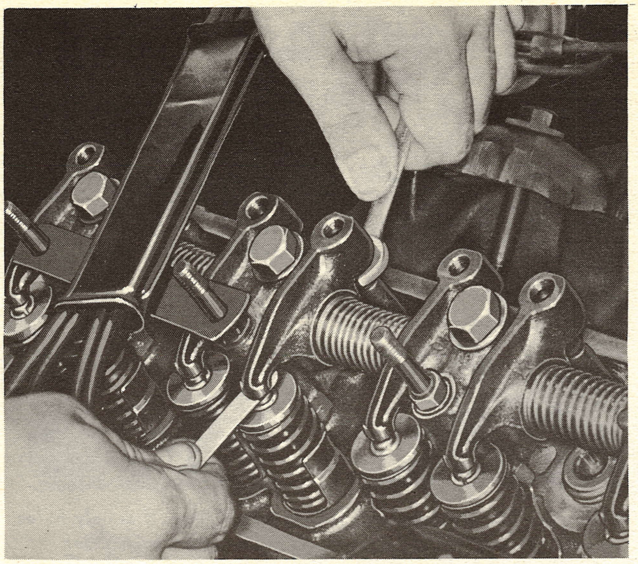
It should be evident that accurate adjustment is impossible if the various contacting surfaces are worn to untrue dimensions. See Figs. 16-42 and 16-43. If such parts are not too seriously worn, they can be restored by grinding with equipment made for the purpose. If they are worn enough to be through the case-hardened shell, they should be discarded and replaced with new parts.



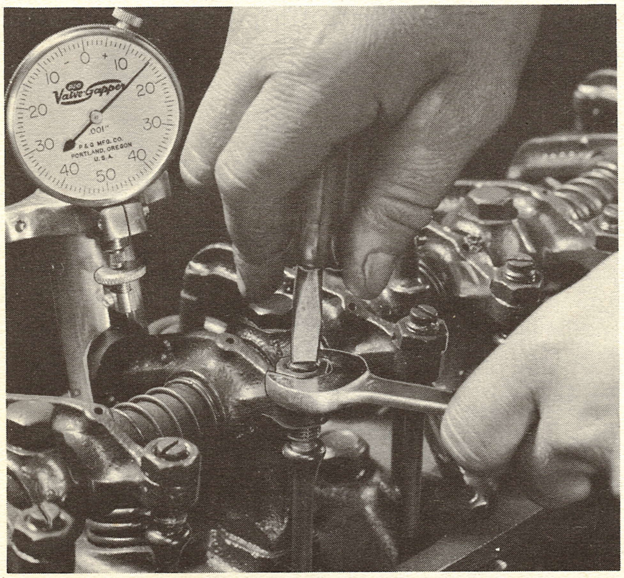
16-43. *Instead of a shaft carrying a number of valve rocker arms, a single stud may be used for each rocker arm as on Chevrolet and Pontiac.*

VALVE TAPPET ADJUSTMENT

Adjustment of the tappet clearance is made by means of a feeler gauge as shown in Fig. 16-44, or with the aid of a special dial gauge as shown in Fig. 16-45. In these cases, the adjustment is accessible being on top an overhead valve engine. In some cases where an L-head engine is mounted low in the frame with



16-44. Method of using a feeler gauge to adjust valve clearance on an overhead valve engine.



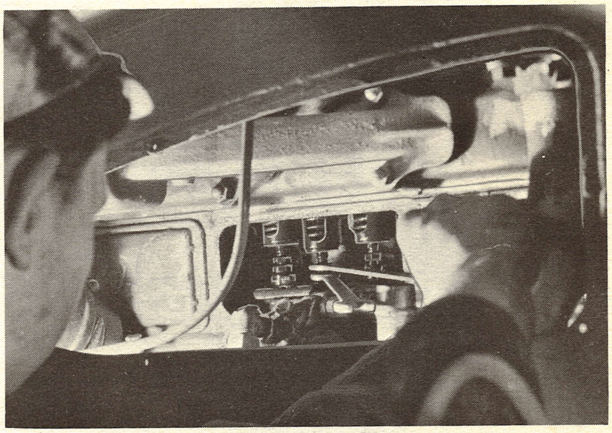
16-45. Use of special gauge to adjust valve tappets on overhead valve engine.

high fenders, it is extremely difficult to get at the valves. In some cases it is necessary to remove the front wheel to get at a detachable panel in the fender, which permits access to the valves. See Fig. 16-46.

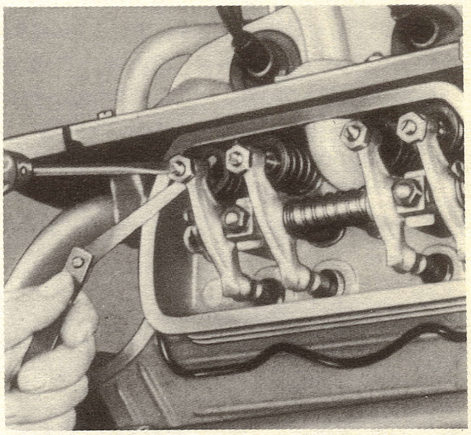
Several Europen engines are of the flat or pancake type with opposed cylinders. In these cases the overhead valves are on the outside of the engine. On the German Volkswagen for example, the engine is a flat four in the rear of the car. Adjustment of the valve clearance is made from under the rear fender on each side. See Fig. 16-47.

In the case of the English Jowett, which also has a flat four, the engine is mounted in front of the front axle. In this construction, the cylinder heads and valve rockers can be removed from either side from under the front fender, after the wheel is removed.

Early English Jaguar engines had overhead valves operated by means of push rods and rocker arms. Later models had a chain driven overhead camshaft, and still later a double overhead camshaft was adopted. The clearance between valve stem end and camshaft is difficult to adjust, as it consists of inserting different thickness pads on the end of the valve stem.



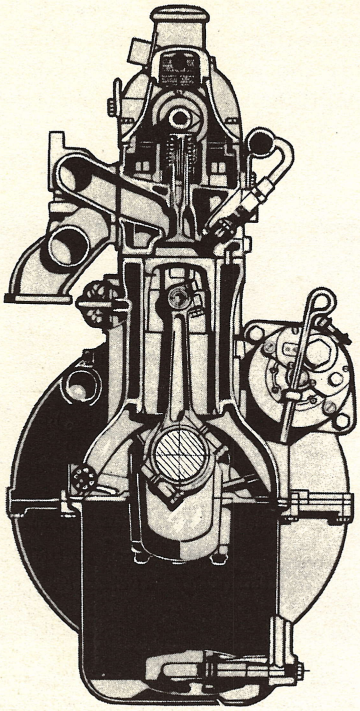
16-46. Removable access panels are provided in some cases where it is difficult to get to valves to adjust them.



16-47. Volkswagen valves can be adjusted from under the rear fenders on each side.

The English Morris and the Wolseley engines have overhead camshafts driven by a shaft and gears. In this case, the valve clearance is adjustable by means of a threaded collar between the cam and the valve stem. See Fig. 16-48.

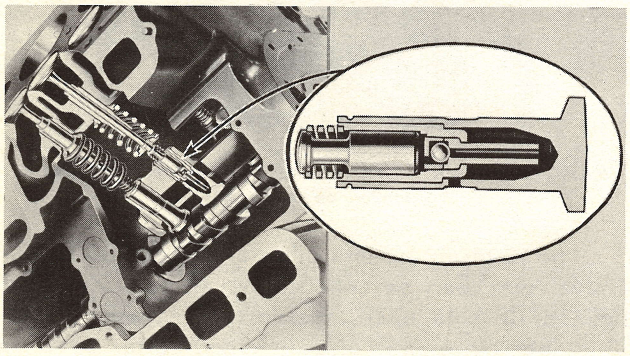
Special wrenches are required to make the adjustment on these engines.



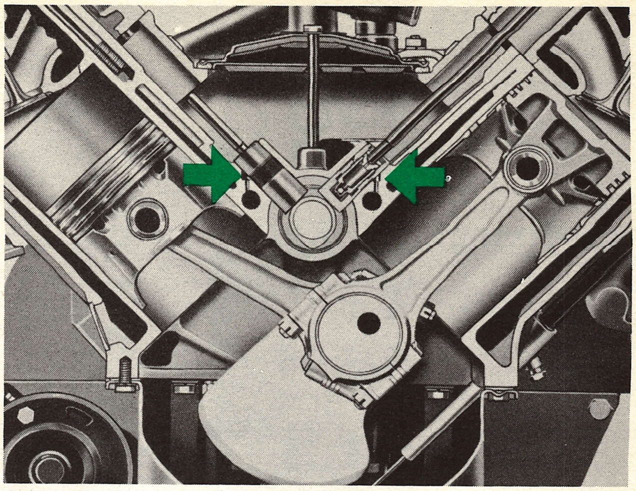
16-48. Special tools are required to adjust the clearance between cam and valve end on the Morris engine.

HYDRAULIC VALVE LIFTERS

Many engines have self-adjusting valve lifters of the hydraulic type which operate at zero clearance at all times. See Fig. 16-49. In this case, the engine oil circulation system supplies a constant flow of oil under pressure to the lifters. See Fig. 16-50. Operating at zero clearance, these lifters compensate for changes in engine temperature, adapt automatically for minor wear at various points, and thus provide ideal valve timing as well as freedom from noise.

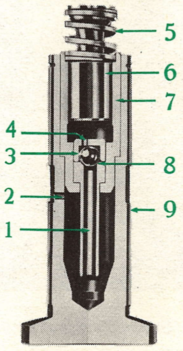


16-49. Hydraulic valve lifters as installed on L head engine.



16-50. On this overhead valve installation, the oil supply holes are drilled directly into the oil galleries on each side.

One type of hydraulic lifter is shown in Fig. 16-51. In this illustration, 1 is the tube that carries the oil coming in at 2 from the engine supply to the ball check 3, which rests on seat 8. The supply chamber inside the body 9 is kept full of oil at all times, when the engine is running, as port 2 is connected into the engine oil pressure system. Similarly, the oil--being under pressure--can raise the ball 3 and keep the pressure chamber below 6 full at all times, by going through port 4.



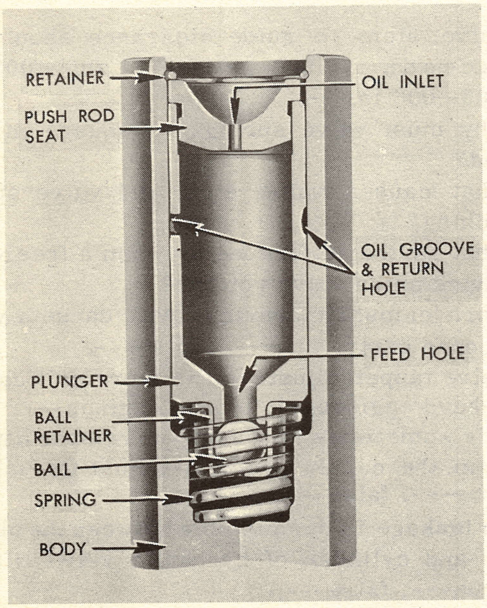
16-51. Cut-away section of hydraulic valve lifter shows how oil from the engine oiling system enters the lifter assembly through port hole 2 located in an external groove.

When the lifter body 9 rests on the heel of the cam, spring 5 pushes the plunger 6 into contact with the end of the valve stem. This spring is not strong enough to lift the engine valve off its seat. This gives zero tappet clearance. As the plunger lifts, it creates a slight vacuum in the pressure chamber, and oil is drawn through port 4, through tube 1 and seat 8, past the ball check 3.

As the cam rotates and lifts body 9, it carries cylinder 7 with it. This tends to push plunger 6 down into cylinder 7. The pressure thus generated causes the ball check valve to seat and hold the oil in the pressure chamber under plunger 6. As oil, for all practical purposes is incompressible, the valve is lifted on a column of oil and supported thus while the valve is open. When the valve seats, the foregoing cycle is repeated.

There are several types of hydraulic valve lifters in use and they vary somewhat in design. Another type is shown in Fig. 16-52. However, they all work on the same general principle.

There is a small amount of oil leakage between the lifter plunger and the cylinder while the engine valve is off its seat. This is desirable in order that the valve clearance be adjusted to zero each time it is opened. This clearance must be controlled closely as excess leakage at this point would reduce the valve lift. The leakage rate is specified by the manufacturer who also supplies tools for checking the leakage rate. See Fig. 16-53.

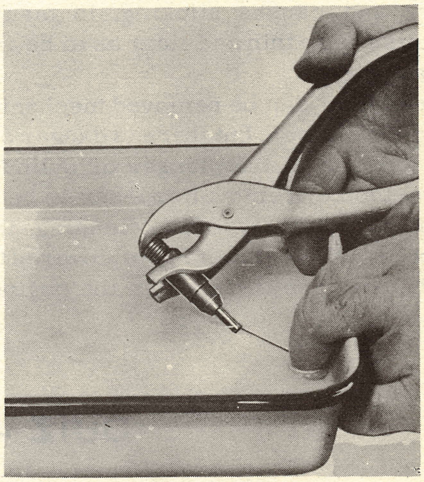


16-52. Another typical hydraulic lifter which differs in design, but operates on the same principle as the example described in the text.

HYDRAULIC LIFTER PROBLEMS

While hydraulic valve lifters do provide ideal valve operation, like any other mechanical device, they are subject to certain difficulties and require some attention. It should be obvious from the foregoing that clearances between the moving parts must be controlled closely.

This necessity for controlled clearance has caused some difficulty in operation due to dirt or varnish, causing the lifters to stick. The plunger and cylinder are often held to dimensional tolerances of one-tenth of a thousandth of an inch or less in manufacture, and then selectively assembled. That is, different plungers are tried in different cylinders until a pair is found that fits closely enough without being too tight.



16-53. Special tools are available for checking the leak-down rate of hydraulic valve lifters.

For this reason they should not be mixed up when they are removed for service. Each plunger should be kept with the cylinder in which it operates.

With clearances of this nature, it will be understood that the tiniest fleck of carbon, a fine thread of lint from a wiping cloth, a speck of dust, or any foreign matter whatever will wedge between the plunger and cylinder, and cause them to stick. Anything as large as an eyelash or hair will put it completely out of order.

For this reason, it is necessary to keep the engine oil CLEAN when hydraulic lifters are used. The very best grade of oil must be used in the engine and the oil MUST be changed frequently. Oil filter cartridges must also be replaced regularly.

Another reason for using the best possible oil in the engine and changing it frequently comes about from a general increase in driving speeds for long continued periods. Highways and cars are such that car owners do not hesitate to drive at high speeds for hours at a time. Such operation is certain to generate heat, and the inside of the engine and the oil, reach temperatures that are destructive to the oil.

The oil often becomes hot enough to "crack" some of the petroleum fractions (just as in an oil refinery) and in decomposing, these elements form a "varnish" or "lacquer." This varnish-like material collects on the plunger and in the cylinder, and causes sticking. In many cases this varnish is so thin and clear as to be invisible to the naked eye.

Such deposits can be removed mechanically by brushing or friction, but there is danger of harming the surface of the plunger or cylinder. The safest method of removal appears to be the use of chemical solvents. After cleaning, the units should be dried by air and kept covered to avoid dust until they are installed in the engine. They should not be wiped with a cloth for fear that a thread of lint will adhere to them.

It is clear that such parts must be handled with extreme care when out of the engine. If dropped on the bench or floor, or dropped one on another, a nick or scratch may result that would cause them to stick. When clean and dry, the plunger should fall into or drop out of the cylinder of its own weight.

When reinstalled, the clearance should be checked to make sure there is enough. The tappet clearance dimension is much greater than with mechanical linkage, and varies considerably among the different makes. The manufacturers' recommendations should be obtained and followed. As in the case of any other valve tappet adjustment, the lifter must be on the heel of the cam when measured. The usual procedure is to turn the engine until the ignition distributor rotor is in the firing position for the cylinder to be checked. This assures that the piston is on top center and both valves completely closed.

QUIZ - VALVE SERVICE

1-A valve should be discarded if the stem is bent more than: .002---, .004---, .006--- in.

2-A valve interference angle should be cut on: the combustion chamber side---, the port side---, both sides---.

3-A narrow valve seat will dissipate the heat better than a wide one. True---, false---.

4-The valve seat should be concentric with the guide within: .001---, .002---, .003--- in.

5-Valve seat inserts are not used in cast iron cylinder blocks or heads. True---, false---.

6-Describe an interference fit for a valve seat insert.

7-Name three ways of shrinking inserts.

8-Heat dissipation is better when valve guides are not used. True---, false---.

9-Leaking intake valve guides: cause excess oil consumption---, upset carburetor adjustment---, both---.

10-Valve stem seals are placed: on the valve stem---, in the valve guide---, either---.

11-Valve stem to guide clearance should not exceed: .003-.004---, .004-.005---, .005-.006 in.---.

12-Why must valve springs be square on each end?

13-What causes valve stem and valve spring etching?

14-What is the difference between a free valve device and a valve rotator?

15-Worn camshaft bearings will cause a valve to open early. True---, false---.

16-Valve tappet adjustment is more critical on: L-head engines---, I-head engines---.

17-It is sometimes necessary to remove a wheel from the car in order to adjust the valves. True---, false---.

18-No leakage is permissible between the plunger and cylinder of hydraulic valve lifters. True---, false---.

19-What is meant by a selective fit?

20-Clean cloths must be used to wipe parts of hydraulic valve lifters. True---, false---.

ENGINE TROUBLE-SHOOTING

Trouble-shooting is a process of reasoning supported by deduction and elimination. As a defect in one part may have a definite relation to trouble in another--perhaps remote spot--the trouble-shooter must of necessity have the ability to keep the entire automobile in mind at all times. This requires mental alertness as well as specific knowledge.

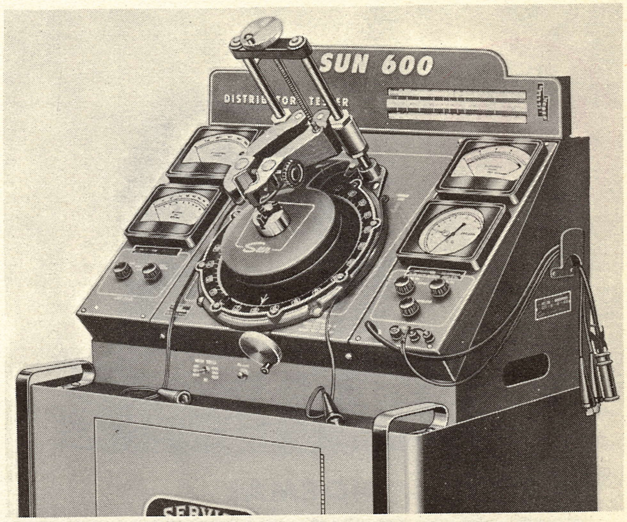
Trouble-shooting in its most elementary form consists of "shorting out" a spark plug with a screwdriver to locate a misfiring cylinder. In its most advanced form it involves the use of elaborate testing equipment. A good example of this is the equipment widely used to determine the condition of the electrical system in an automobile.

ALLEN
TIMING LIGHT
ENGINE CONNECTIONS
GROUND POLARITY

17-1. One type of oscilloscope is included in this ignition checking equipment.

TESTING EQUIPMENT

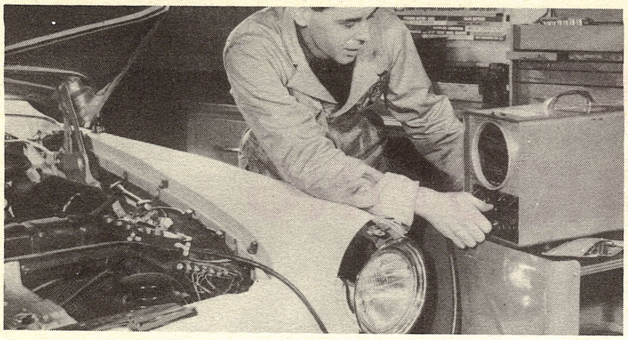
Typical test stands are shown in Figs. 17-1 and 17-2. These instruments are provided with accurate voltmeters, ammeters, gauges and other testing devices. When used properly, it is possible to locate leaks or breaks in the wiring of the automobile, determine the amount of current developed or consumed by any part of the electrical system. Some of these instruments indicate what is going on inside the engine combustion chamber. See Figs. 17-3 and 17-4.



17-2. This test stand has a power-driven ignition distributor tester in addition to other gauges used in engine analysis.

Such equipment also facilitates precise adjustment of the carburetor, ignition and engine in general as well as the generator, voltage regulator, etc. This equipment is covered in detail in the electrical and carburetor sections of this text.

Equipment is also available and coming into extended use for testing the entire automobile



17-3. *An oscilloscope in use with the operator watching the pattern on the screen.*

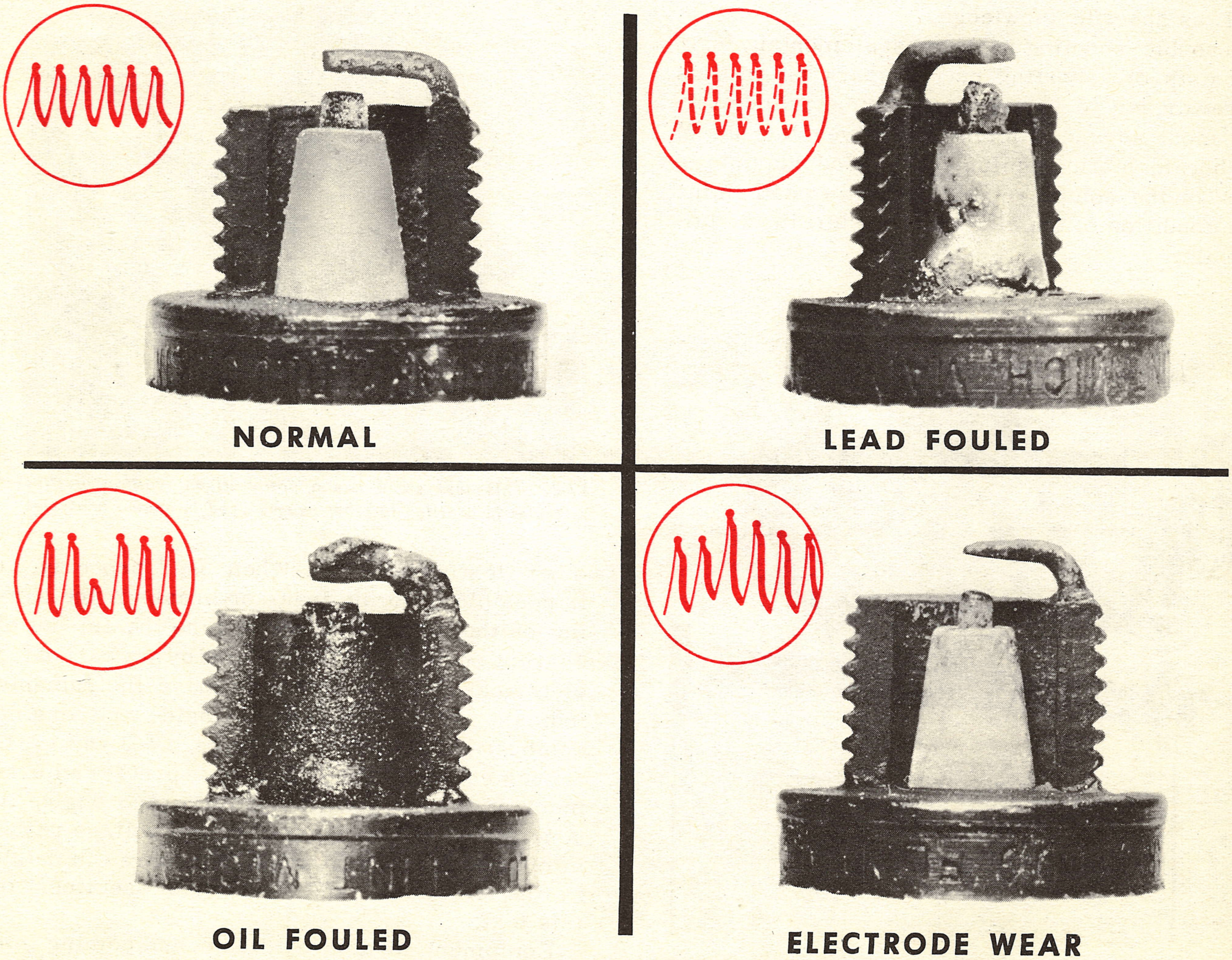
under road operation conditions. These instruments are known as dynamometers, and are operated by the driving wheels of the automobile. See Fig. 17-5.

Dynamometers are also widely used in the testing and adjustment of automatic transmissions. See Fig. 17-6.

Other small individual instruments are used to test engine compression, test engine lubrication systems, carburetor adjustment, etc. These instruments are all essential and MODERN AUTOMOBILES CANNOT BE SATISFACTORILY REPAIRED AND ADJUSTED WITHOUT THEM. For example, many engines are rebuilt because they use an excessive amount of oil only to find that the rebuilding did not stop the use of excessive oil. Equipment for testing the oil system would have located the source of the trouble.

HIGH OIL CONSUMPTION

Quite often high oil consumption is blamed on the piston rings. The engine is disassembled, the cylinders reconditioned, and the new piston rings carefully fitted. Upon reassembly, the engine may use more oil than before. The mechanic often hopes the new rings will "wear in" to a better fit in the cylinders, and advises the car owner



NORMAL

LEAD FOULED

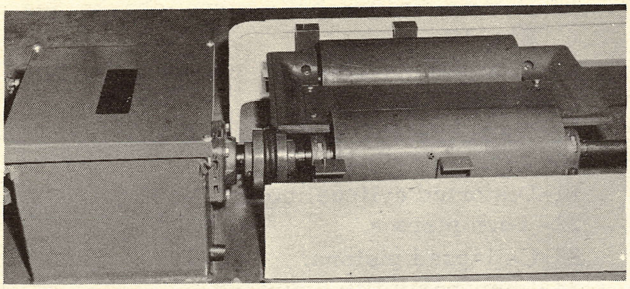
OIL FOULED

ELECTRODE WEAR

17-4. *Spark plug conditions as portrayed by wavy lines on the oscilloscope screen.*

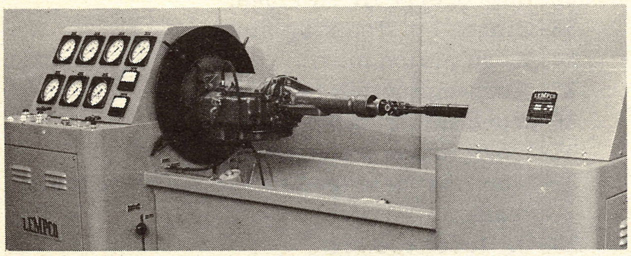
to drive the car a few hundred miles.

The driving seldom does any good, and the engine is again disassembled to find the trouble.

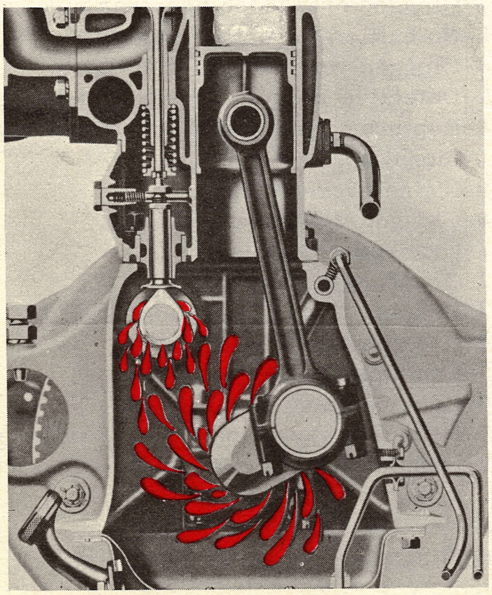


17-5. On this floor type dynamometer, the car is driven over it and stopped with the drive wheels on the rollers.

While worn piston rings and cylinder walls may cause increased oil consumption, there are a great number of other things that are at fault either singly or in combination. In most cases the oil is leaking out of one or more of the pressure lubricated bearings, and is being splashed or thrown up into the cylinders under the pistons in such large quantities, that no piston ring can control the excess. See Fig. 17-7. This is covered under piston rings elsewhere in this text.



17-6. Typical automatic transmission test stand.

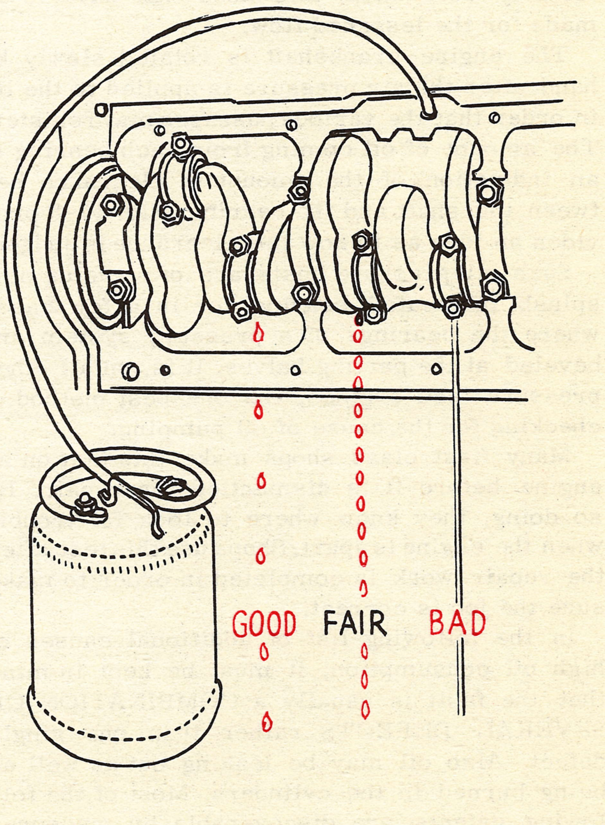


17-7. Loose bearings can cause such a flood of oil to be thrown up on the cylinder walls that no piston ring can control oil consumption.

OIL PRESSURE TEST

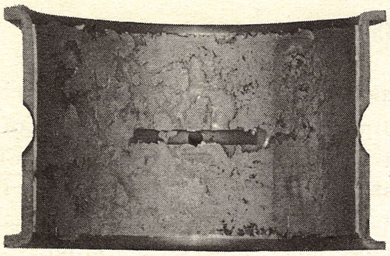
An oil pressure test is made before the engine is disassembled with the aid of special equipment made for the purpose. See Fig. 17-8. Such a test will ordinarily disclose the following defects:

1-Worn connecting rod bearings.
2-Loose connecting rod bearings.
3-Excess side clearance in connecting rod bearings.
4-Worn main bearings.
5-Loose main bearings. See Fig. 17-9.
6-Excess crankshaft end play.
7-Worn camshaft bearings.
8-Worn camshaft journals.
9-Worn crankshaft journals.
10-Oil leaking past front and rear main bearings.
11-Defective crankshaft seals.



17-8. An indication of how clearance in the engine bearings is judged by the amount of oil under pressure flowing from the sides of the bearings.

12-Leaking seal plug at rear camshaft bearing.
13-Broken oil line.



17-9. This bearing insert might not cause a knock, but certainly would leak oil.

The testing equipment can be used with the engine in or out of the car, as it is a special pressure tank connected into the oil line. The oil pan is removed so that each of the bearings can be observed. The pipe from the test tank is connected to the engine oil line. It is customary to use SAE 20 oil in the pressure tank. The oil and the engine should be at a comfortable temperature when the test is made. If in an uncomfortably cold shop, allowance will have to be made for the lessened flow.

The engine crankshaft is rotated slowly by hand after the air pressure is applied to the oil in order that the various passages may register. The amount of oil coming from each bearing is an indication of the amount of clearance between the shaft and the bearing. Fig. 17-8 provides an idea as to how this clearance is judged.

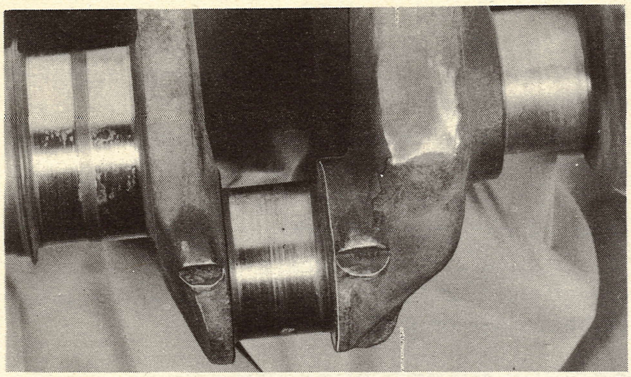
Such oil pressure tests are of no value on a splash lubricated bearing, or in a few cases where the bearings of a pressure system are beveled at the parting halves. It is, on all other pressure feed engines, the one best method of checking for the cause of oil pumping.

Many first class shops make this test on an engine before it is dismantled for repair. By so doing, they know where to look for trouble when the engine is apart. Shops use this test after the repair work is completed in order to make sure the job is correct.

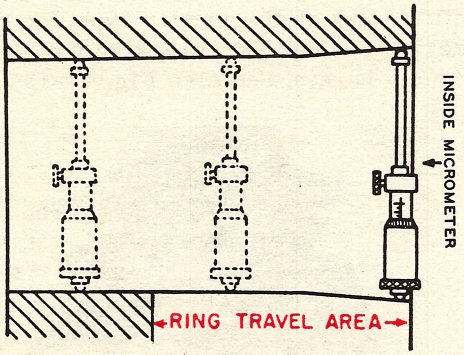
In the following list of additional causes of high oil consumption, it must be kept in mind that the fault is usually a COMBINATION OF SEVERAL DEFECTS rather than one single defect. Also oil may be leaking out as well as being burned in the cylinders. Most of the following defects are discoverable by measurement, or, are susceptible of adjustment as outlined previously in this text. All others can be detected by observation.

14-Bent or twisted connecting rods.
15-Bent crankshaft.
16-Out-of-round crankshaft journals.
17-Damaged crankshaft journal cheeks. See Fig. 17-10.
18-Damaged crankshaft oil slingers and seals.
19-Worn cylinder bores. See Fig. 17-11.
20-Tapered cylinder bores.
21-Distorted cylinder bores. See Fig. 17-12.
22-Worn pistons.
23-Collapsed pistons.
24-Improperly fitted pistons.
25-Stopped up piston drain holes.
26-Worn piston ring grooves.
27-Worn piston rings.
28-Wrong size piston rings.
29-Distorted piston rings.
30-Incorrectly installed piston rings.
31-Rings too tight in ring grooves.
32-Improperly fitted rings.
33-Clogged piston ring slots.
34-Worn piston pins.
35-Worn piston pin bushings.
36-Worn intake valves.
37-Worn intake valve guides.
38-Worn or damaged intake valve or guide seals.
39-Oil level too high.
40-Excessive oil pressure.
41-Clogged oil return from valve chamber.
42-Clogged oil return from timing gear case.
43-Clogged oil filter.
44-Clogged crankcase breather pipe.
45-No baffle in breather pipe.
46-Clogged vents in clutch housing.
47-Defective vacuum booster diaphragm.
48-Ruptured diaphragm in transmission modulator.
49 Engine overheating.
50-Clogged water jackets.
51-Cracked crankcase.
52-Crankcase gasket leaks.
53-Leaking timing gear case gasket.
54-Leaking oil filter gasket.
55-Leaking oil filter connections.
56-Leaking valve cover gasket.
57-Defective gasket on external oil pump.
58-Defective gasket on oil pressure regulator.
59-Leaking oil pan drain plug.
60-Miscellaneous other oil leaks.

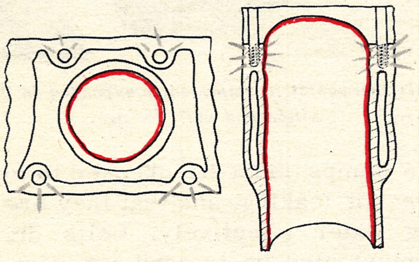
Among the reasons listed in the foregoing are "overheating" and "clogged water jackets." These items cause oil to be consumed in two ways. Due to the increased engine temperature, more oil is vaporized and burned up when the engine overheats. Also overheating due to a clogged water jacket will result in cylinder wall distortion as previously explained. When the cylinder distorts, the rings cannot seal and the oil passes between them and the cylinder walls.



17-10. *This shaft has been gripped in vise jaws so tightly that the edges of the cheeks were deformed.*



17-11. *Here we have wear over all the ring travel area, with the customary taper at the top of the cylinder.*



17-12. *Exaggerated illustration of cylinder distortion caused by unequal or excessive tightening of cylinder head bolts.*

ENGINE OVERHEATING

Locating the cause of overheating in an automobile engine is often a true test of the ability of a trouble-shooter, because he must think of almost all parts of the entire automobile simultaneously. There are eight basic defects that must be kept in mind when overheating occurs:

1-An accumulation of rust or lime on the inside surfaces of the water jacket which will interfere with the heat leaving the cylinder to enter the coolant.

2-A loss in the efficiency of the pumping means a reduction in the volume of water being used to carry the heat from the cylinder block to the radiator.

3-Any mechanical restriction or partial stoppage of any water passages in the water jackets, hose connections, thermostats, radiators, etc., which will reduce the volume of water circulation.

4-Anything that will reduce the heat carrying ability of the water, such as air leakage into the water and resultant bubbles or aeration.

5-Any leakage or loss of water, which will reduce the volume of water available to carry the heat from the cylinders to the radiator.

6-An accumulation of lime, rust or sludge in the radiator passages which will act as an insulator, to prevent the heat flowing from the water to the metal radiator core. This same accumulation reduces the size of the passages, and thus reduces the amount of water going through the core. Therefore less heat is extracted.

7-Any restriction in the air flow through the core of the radiator. This might be blocked air passages, obstruction in front of the radiator, faulty fan action, etc., or anything that reduces the volume of air coming into contact with the radiator core.

8-Any condition of use or mechanical condition of the automobile, that will increase the amount of heat generated by the engine.

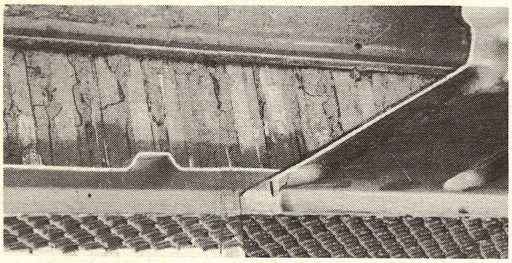
Most important of all, it must be borne in mind that almost always the trouble is the result of several minor defects, rather than one major fault.

For example, a light coating of lime in the water jackets, plus some dirt on the radiator core, plus a slipping fan belt, plus a long hill, plus a hot day and we have a "boiler." No single one of these things would be liable to cause trouble, but in combination they can cause serious overheating. Therefore, when trying to overcome difficulty in a cooling system, it is necessary to make a thorough check rather than to decide that the trouble is in the radiator.

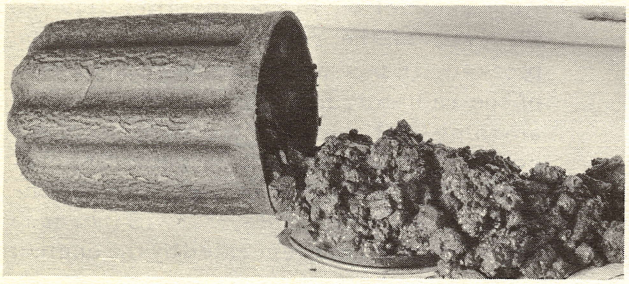
ANTI-FREEZE PROBLEMS

Another common cause of overheating is boiling away of volatile type anti-freeze in heavy, slow moving traffic. This is especially true if the cooling system has any minor defects that went undetected during colder weather. Such defects might have been remedied at the time the anti-freeze was installed.

Before filling a cooling system with anti-freeze it is imperative that the system be checked to make sure that there are no accumulations of rust, mud or scale, Fig. 17-13, that the system is free from leaks, and is in good working order. Filters installed in cooling systems are an effective means of keeping them free from accumulation of dirt and rust. See Fig. 17-14.



17-13. Section of radiator, showing accumulation of rust and scale blocking the free flow of coolant.



17-14. Expended Fram Radiator and Water Cleaner Cartridge showing dirt, rust, and sludge removed from an automotive cooling system.

SCALE REMOVAL

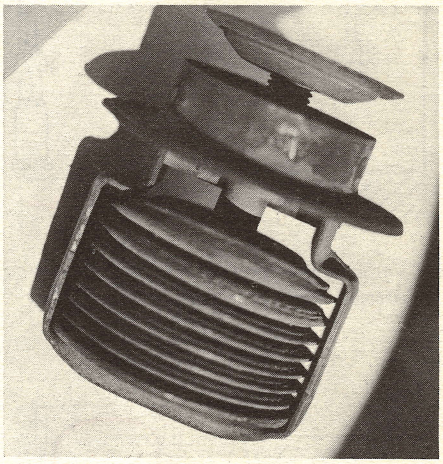
Minor accumulations of scale and trash can be removed from the cooling system with the aid of prepared chemicals and reverse flushing. Reverse flushing consists of circulating water through the system in the direction opposite its normal flow. Reverse flushing is usually done with the aid of special equipment which forces water through under pressure while at the same time injecting air periodically to assist in jarring the scale loose.

The chemicals loosen the scale, and the reverse pressure flushing carries it out of the engine block and head. The same equipment may also be used on the radiator. The chemical manufacturers' instructions must be followed closely to avoid damage.

In case the deposits are too heavy to be removed by the foregoing method, they can often be cleaned out by power purging equipment. This equipment surges powerful streams of chemicals through the system in alternate directions and is claimed to clear out the most stubborn accumulations.

COOLING SYSTEM CHECKING

Cooling system thermostats should be examined to make sure they are in good operating condition, and of the proper type for the anti-freeze to be used. This checking was described previously herein. See also Fig. 17-15.



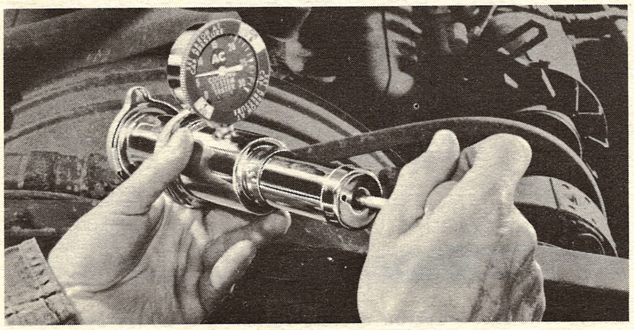
17-15. This thermostat is permanently expanded in the open position and unfit for use.

Water pumps must be checked to make sure they are not leaking, and that they are actually pumping water effectively. Belts driving the pumps must also be in good condition, and adjusted to the proper tension.

Before filling a cooling system with anti-freeze, it is important that there be no cylinder head gasket, or water jacket leaks, which might permit anti-freeze to enter the cylinders or oil pan. This is particularly true if a permanent type anti-freeze is to be used. Should that occur, the mixture of the permanent type anti-freeze with the hot oil may form a gummy substance, causing pistons and rings to seize in the cylinders. A special chemical is available which is claimed to dissolve this gum, but it is difficult to be sure the oil lines are all clear without complete disassembly of the engine.

To check for a defective cylinder head gasket, the engine should be brought to operating temperature. The water level in the radiator is then brought up to the top of the filler pipe. Then, with the engine operating at a speed of approximately 45 m.p.h., the water in the top of the fill pipe is observed for evidence of bubbles which would indicate explosion pressure escaping into the water.

Another means of checking the cooling system at operating temperature under pressure is with the aid of a special tester which is available, as shown in Fig. 17-16. This same equipment can also be used to test radiator pressure caps.



17-16. *With these cooling system testing instruments, enough pressure can be applied to locate leaks that might otherwise go undetected.*

Excessive water coming from the muffler tail pipe is an indication of a defective cylinder head gasket or cracked water jacket. However, there is likely to be confusion in such conditions because of the difficulty in distinguishing between a cooling system leak, and the normal amount of water resulting from condensation of combustion gasses.

OVERHEATING CAUSES

Returning now to our eight basic defects in cooling systems, we can list under No. 1:

- A-Scale and rust in cylinder head.
- B-Scale and rust in cylinder block water passages. See Fig. 17-17.

Under No. 2 we can list:

- A-Worn water pump impeller or housing.
- B-Sheared impeller pin or key.

Under No. 3 we find:

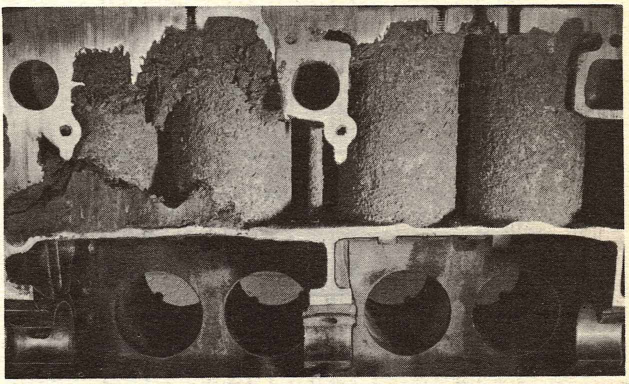
- A-Incorrect cylinder head gasket.
- B-Defective thermostat.
- C-Improper thermostat.
- D-Clogged radiator tubes.
- E-Undersize radiator core.
- F-Clogged radiator hose.
- G-Collapsed radiator hose.
- H-Water distribution tube clogged or rusted out.

Under No. 4 we can have:

- A-Cylinder head gasket blown.
- B-Leaking water pump seal.
- C-Oversupply of anti-freeze.
- D-Undersupply of coolant.
- E-Foaming of coolant.

Under No. 5 we list:

- A-Leaking cylinder head.
- B-Leaking cylinder head gasket.
- C-Leaking cylinder block.
- D-Leaking expansion plugs.
- E-Leaking water pump housing.
- F-Leaking water pump shaft.
- G-Leaking water pump gasket.
- H-Leaking drain cocks.
- I-Leaking radiator core.
- J-Leaking radiator tank.
- K-Leaking overflow pipe.
- L-Leaking cap gasket.
- M-Leaking radiator hose.
- N-Leaking heater core.
- O-Leaking heater hose.
- P-Leaking transmission oil cooler or connections.



17-17. *Water jacket cut open to show typical accumulation of rust and scale.*

Under No. 6 we can include:

- A-Rust deposits in radiator tank.
- B-Bent or loose radiator baffle plate.

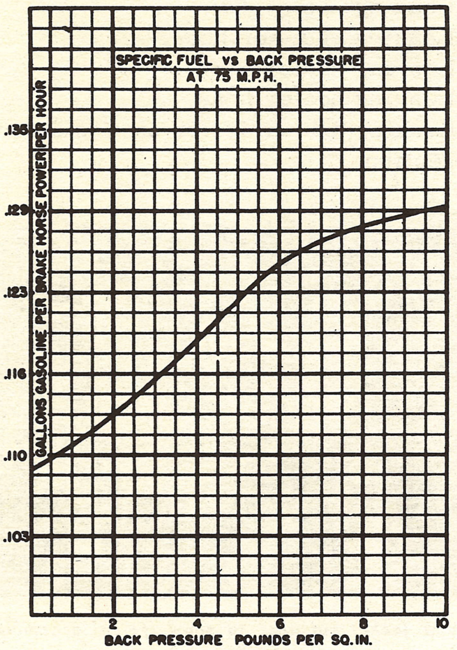
Under No. 7 we should have:

- A-Bent radiator fins.
- B-Obstructed air passages.
- C-Paint on radiator.
- D-Bent fan blades.
- E-Fan shroud bent or missing.
- F-Worn fan belt.
- G-Loose fan belt.
- H-Worn drive pulleys.

No. 8 is of course a rather wide assortment of defects:

- A-Cylinder block hot spots.

B-Leaking valves.
C-Leaking piston rings.
D-Worn timing chain.
E-Valve timing late.
F-Ignition timing late.
G-Defective ignition spark advance.
H-Plugged vacuum line to distributor.
I-Carburetor mixture too rich.
J-Clogged muffler. See Fig. 17-18.
K-Kinked tail pipe.
L-Defective radiator pressure cap.
M-Low engine oil level.
N-Low oil pressure.
O-Low automatic transmission oil level.
P-Automatic transmission overheating.
Q-Overloaded engine.
R-Stiff engine (After overhaul).
S-Slipping clutch.
T-Dragging brakes.

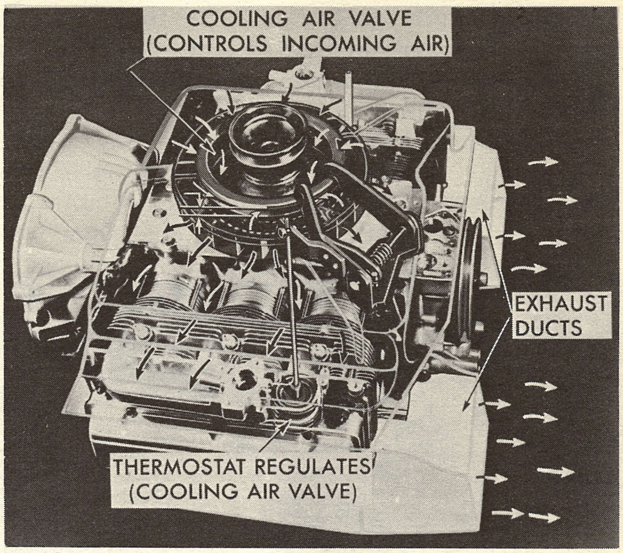


17-18. Fuel consumption and engine heat rise rapidly with increased exhaust back pressure.

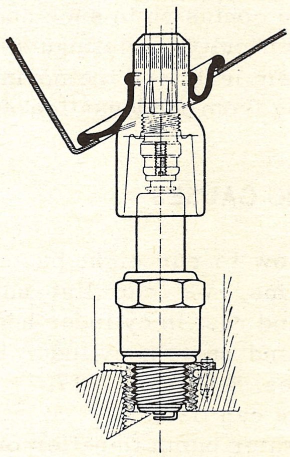
AIR COOLING PROBLEMS

Many of the items listed in Nos. 7 and 8, in the foregoing apply to air cooled engines as well as water cooled engines. As an example; an air cooled engine should never be overloaded, or "lugged," because the cooling system is dependent on the fan speed. Transmission gears should be shifted as needed to maintain engine speed at a good level.

Air cooled automobile engines are usually enclosed entirely in a sheet metal housing or shroud. See Fig. 17-19. The cooling air volume entering this shroud is controlled by an automatic thermostatically operated valve. Obviously the air flow cannot be controlled and directed where it is wanted, if there are any air leaks in the shroud. Even the spark plugs are sealed to the shroud as shown in Fig. 17-20. These seals must be in good condition and properly installed.

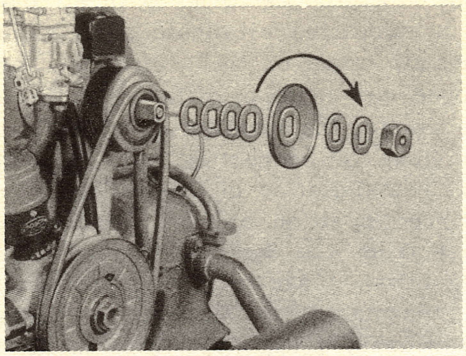


17-19. The entire Corvair cooling system is enclosed by a sheet metal housing.



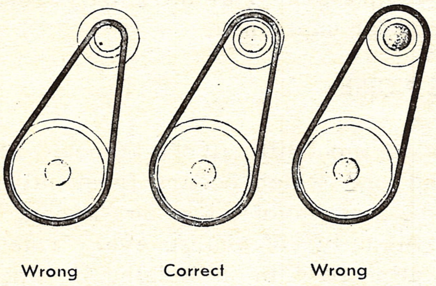
17-20. Location of seals on Volkswagen spark plugs.

The Volkswagen has an unusual method of adjusting the fan belt tension by fitting more or less spacer washers between the two pulley halves. See Fig. 17-21. Removal of washers increases the effective diameter of the driven pulley. When all washers have been removed, a



17-21. Method of transferring spacing washers to tighten Volkswagen fan belt.

new belt is installed. The correct relation is shown in Fig. 17-22. When washers are removed from between the pulley halves, they are placed between outer pulley half and pulley nut, and left there until needed. DO NOT attempt to remove or replace this belt by stretching it over either of the pulley flanges. Additional causes for overheating of air cooled engines are:



17-22. Proper and improper pulley relations on Volkswagen engine.

- A-Dirt on cooling fins.
- B-Oil cooler dirty.
- C-Air leaks in shroud or seals.
- D-Loose spark plug boots.
- E-Thermostat stuck in closed position.
- F-Improper adjustment of air control ring.

RELATED TROUBLES

It will be seen from the foregoing that many engine defects are common to both high oil consumption and overheating. There is a definite relation between the two, and searching for the cause of either trouble will often disclose the need for correction in either or both the oil and water circulation systems.

The same thing is true of the entire automobile. As an example; suppose we are trying to eliminate the cause of repeated burning of the exhaust valves in an engine. We can be reasonably sure that some defect exists in this particular automobile because thousands of the same make and model are operating satisfactorily without burning the valves.

We also know the valves are running too hot or they would not burn. Therefore the question is:

1-Are the exhaust valves being subjected to an excessive amount of heat?

or

2-Are the valves--for some reason--unable to dissipate the normal amount of heat to the cooling system?

Among the things that will cause the generation of excess heat are:

- 1-Extreme high speed.
- 2-Unusual engine overload.
- 3-Excessively lean carburetor mixture.
- 4-Engine "hot spots" and/or overheating.
- 5-Late valve timing.
- 6-Late ignition timing.

Each of the foregoing are quickly and easily checked. If no defects are discovered, we may then suspect that the heat is being retained in the valves instead of being dissipated to the cooling system. Many things can cause or contribute to this condition. It is usually a combination of several things.

Among the defects to be found in many cases are the following:

- 1-Valve seat too narrow.
- 2-Worn valve guide and/or valve stem.
- 3-Weak valve springs.
- 4-Sticking valve stems.
- 5-Incorrect valve tappet clearance.
- 6-Loose valve seat insert.
- 7-Valve guides loose in block.

The foregoing and many other defects were discussed in detail in the valve section of this text.

LOW OIL PRESSURE

In most cases of low oil pressure, it will be found that the oil pressure is satisfactory when the engine is first started up, and then drops as the engine warms up. Such a condition is almost positive proof that excessive clearance exists at some point, or points, such as connecting rod bearings, main bearings, camshaft bearings, etc. The reason is that the cold oil has thickened, and does not flow as readily through the clearance. When the oil heats up and thins out, it flows through the worn bearings so fast that the pump cannot maintain sufficient pressure.

EXHAUST BACK PRESSURE

If the exhaust pipe, muffler or tail pipe should be partially restricted, the heat is unable to escape readily, and the temperature of the exhaust valves will rise. It might not seem logical to inspect the tail pipe, muffler, exhaust line and manifold heat control in order to find why valves burn, but it is desirable to eliminate them as a possible source of trouble before dismantling the engine to check the valves.

EXCESSIVE VIBRATION

A process of elimination is often the only way to discover where the trouble lies. Consider the case where there is a pronounced vibration in the car at a certain speed range. First of all it is necessary to determine whether the unbalance is in the engine or the chassis, or both.

If it is in the engine or the parts that rotate with the engine, the vibration should occur at the critical engine speed when the car is not in motion. If it is in the chassis, it will occur only when the car is operated at the critical speed. It is most likely to be found in the chassis, because the engine assembly is carefully balanced at the factory. Out-of-balance tires and propeller shafts are a common cause of chassis vibration.

UNBALANCE CORRECTION

Wheel unbalance may be in the wheel itself, but is more often found in the tire or brake drum assembly. Each wheel can be checked easily with a wheel spinning device, and the correction made by the addition of weights as described in the wheel alignment section of this text.

Another frequent cause of chassis vibration is unbalance in the driveshaft or universal joints. Methods of location and correction are described under that subject elsewhere in this text.

If the chassis is eliminated as a source of the trouble, and the vibration is in the engine or related parts, we can carry the process of elimination further. If the vibration can be altered or eliminated by holding the clutch out of engagement, the trouble could be in the clutch or transmission shaft. This of course does not apply to cars equipped with automatic transmissions.

If the trouble is suspected to be in the fan, water pump or generator, the drive belts can be removed temporarily and the engine checked with these units not in operation.

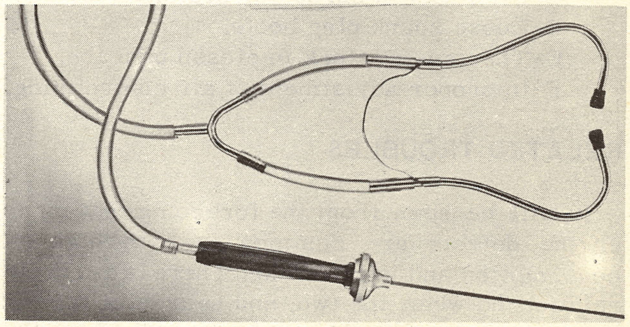
If the vibration continues with all the foregoing possibilities eliminated, it is possible that repair work on the engine or clutch has destroyed the original balance of the engine. For example, the installation of one or more new pistons or connecting rods of unmatched weight, reinstallation of the clutch cover plate in incorrect position, etc. Even the accumulation of dust from the wear of the clutch facing lodging in one place in the clutch housing can cause trouble. With automatic transmission equipped cars, a low fluid level in the transmission may even cause unbalance.

It is often possible to compensate for minor unbalance in the engine and clutch assembly, by installing flat washers under the heads of the capscrews holding the clutch to the flywheel. This is a tedious procedure of trying the washers at different spots around the bolt circle, and checking each time for any improvement or worsening of the vibration. The same procedure is possible where an automatic transmission torque converter or fluid flywheel needs correction for unbalance.

ENGINE NOISE

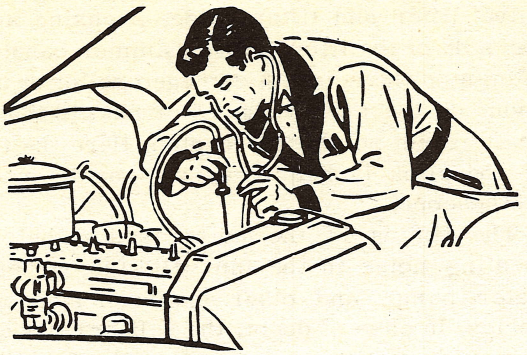
One of the most difficult of all trouble-shooting jobs--and one which occurs frequently--is to locate the source of noise or "knocks" in an engine. Actually, of course every rotating or reciprocating part in the engine is a potential source of noise. In many cases however, certain noises possess characteristics which help identify their origin.

These characteristics vary somewhat between different engines. In most cases it will be helpful to utilize an instrument of the stethoscope type to localize the noise at some definite section of the engine. See Fig. 17-23.



17-23. Stethoscope type of instrument for locating noise in engine parts.

These instruments magnify the intensity of the noise and the sound becomes louder as the instrument nears the origin of the noise. See Fig. 17-24.



17-24. Method of using a stethoscope instrument to locate engine noises.

LOOSE CONNECTING RODS

The conditions of operation under which the noise is heard and the "timing" of the noise are also useful in determining the source. Some noises are louder as the engine speed is increased, or the engine is put under load. For example, a connecting rod bearing that is slightly loose will usually knock loudest around an engine speed of about 40 m.p. h., and of greatest intensity just as the engine goes from a pull to a coast. In other words, just as the driver takes his foot off the accelerator.

A rod in very bad condition will be heard at all speeds and under both idle and load conditions. One rod will make a distinct noise, and if all rods are loose, the noise becomes a rattle or clatter. A pressure lubricated engine seldom becomes this bad, as ordinarily the oil consumption would become so high that the rods would need to be replaced long before they became noisy.

In many cases, slightly loose rods are confused with piston slap or loose piston pins. This is particularly true when all rods are loose, and experience will be helpful in deciding which part is at fault. It is not of too much importance to decide definitely, because the remedy for either fault involves removal of the rod or rods in practically all cases. Measurement and inspection of the parts will then disclose where the trouble lies.

LOOSE PISTON PINS

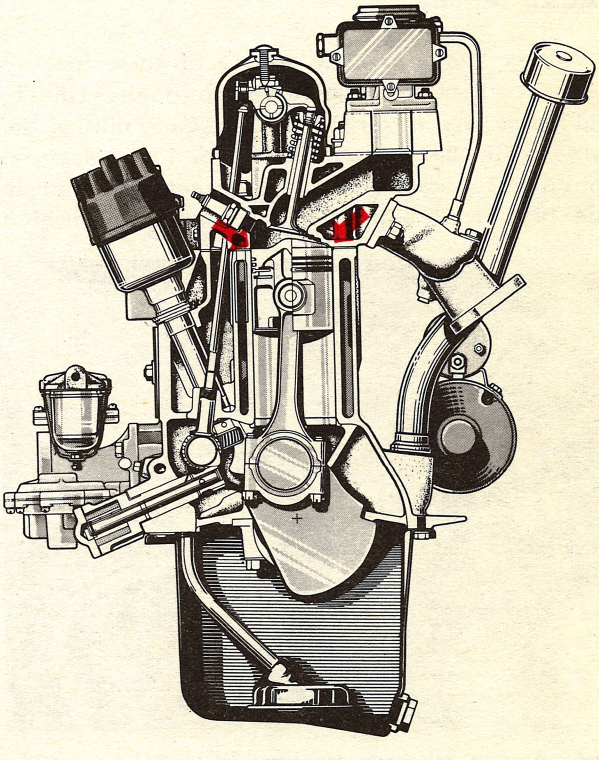
Using a stethoscope is sometimes helpful, as a piston or pin may sound loudest when instrument prod is placed on the cylinder head or block. The rod knock is often loudest with the prod on the crankcase. Shorting out the spark plug on one cylinder may change the intensity of the knock but will not always eliminate it entirely.

Shorting out one or more spark plugs will thus help to locate which cylinder or rod is at fault in cases where the noise is not due to looseness in all cylinders or rods.

PISTON SLAP

There is much confusion between the noise caused by a piston with excessive clearance in the cylinder and a loose piston pin. Either defect produces a click which is quite distinct. If in all cylinders, it becomes a rattle. One indication of piston slap, is a decrease in the noise as the engine warms up. A piston slap is always louder when the engine is cold.

A piston slap may occur in an engine when new piston pins are installed in old pistons. This is particularly true, if the pins are fitted somewhat too tight. Such noise may disappear entirely after the engine is operated a few hundred miles, and the pins have loosened up a bit.



17-25. In a rebuilt engine the piston may strike the edge of the head gasket when the engine is first started.

Loose piston pins usually, but not always, produce a double rap each revolution of the crankshaft--once at the top of the stroke, and again at the bottom. On most engines, the knock is loudest at idling speed, and will become even louder if the spark is advanced. Quite often the knock will be louder, if the plug is shorted out in cases where all pins are not loose.

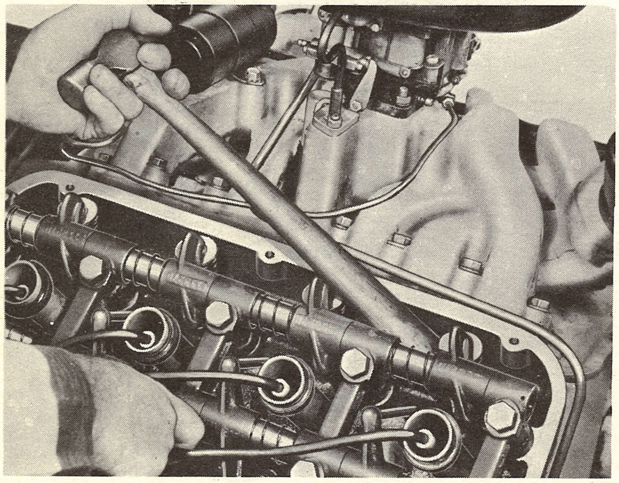
PISTON RING NOISE

The installation of new piston rings will almost surely cause a knock, if the ridge at the top of the cylinder bore is not removed completely before the new rings are installed. Somewhat similar is the condition where the cylinders have been rebored oversize, and the cylinder head gasket extends into the combustion chamber. The piston strikes the gasket, and makes a distinct knock. See Fig. 17-25.

Piston rings that are loose in the grooves will not ordinarily make any noise, as the oil tends to cushion them. If they are excessively loose however--particularly the top ring--they may cause a clicking noise similar to a loose valve tappet. There is a difference in the timing of the click. The rings will click twice each revolution of the crankshaft, while the valve click will be heard once every other revolution.

VALVE NOISES

Valves are a prolific source of noise for two reasons: there are two valves for each cylinder, and there are several points in each unit of the valve train that can create noise. These several points were described and illustrated earlier in this text. It is usually easy to determine which valve or valves are causing the noise by inserting a feeler gauge of suitable thickness between the end of the valve and the tappet, or rocker arm with the engine running. Another method as illustrated in Fig. 17-26 may be helpful on overhead valve engines.



17-26. A noisy valve may sometimes be located by sidewise pressure.

If the clicking is caused by wear between the valve lifter and lifter guide, pressing against the side of the lifter with a hammer handle will often stop the noise. A damaged roller or mushroom on the end of the lifter next to the camshaft is not so readily located. Here the timing of the click is helpful as well as the use of a stethoscope.

The timing of the noise is also helpful in locating noise in the fan belt, fan, generator, water pump, and other engine-driven accessories. In case of doubt, the belt or belts can be removed, and the engine operated a few minutes to see if the noise is thus eliminated.

WORN TIMING GEARS

Another knock that is difficult to diagnose is caused by worn timing gears. Shorting out the plugs has no effect on the noise and it is about the same intensity whether the engine is idling or pulling. A stethoscope is useful in this case to determine where the noise originates. On engines having an exposed accessory shaft, driven from the timing gears, the knock can be made better or worse by pressing firmly on the accessory shaft with a hammer handle.

LOOSE MAIN BEARINGS

A main bearing knock is more of a bump than a knock and can be located by shorting out the plugs near it. The noise is loudest when the engine is "lugging," that is, pulling hard at slow speed. The sound is heavier and duller than a connecting rod knock.

CRANKSHAFT END PLAY

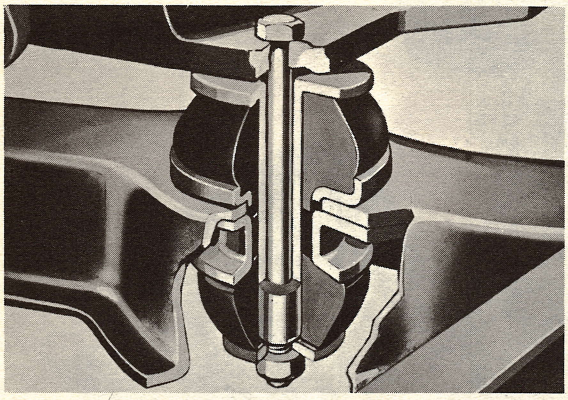
Excessive end play in the crankshaft will produce an intermittent rap or knock that is sharper than a loose main bearing. The noise will usually be affected by applying or releasing the clutch. If the car is equipped with an automatic transmission and has no clutch, the noise is more difficult to diagnose.

LOOSE FLYWHEEL

If the flywheel should be loose on the crankshaft flange, the noise will be similar to a main bearing knock, but ordinarily will not change when the plugs are shorted out. Furthermore, the noise may come and go rather than being constant. One sure test is to turn off the ignition and then turn it on again just as the engine is about to stop. The sudden twist thus applied to the crankshaft will produce the knock in noticeable form.

NOISY ENGINE MOUNTINGS

If the rubber engine mountings are drawn down too tightly, or if the rubber has deteriorated enough to allow the metal parts of the mounting to contact each other a knock may occur. See Fig. 17-27. Such a knock occurs under rapid acceleration.



17-27. *A typical rubber "biscuit" or insulator type of engine mounting pad.*

MISCELLANEOUS NOISES

At times a knock will occur in an engine when all parts have been checked for wear, or even in a rebuilt engine. Such knocks are usually due to misalignment or excessive endwise motion. Too much side clearance in a connecting rod bearing, excessive endwise motion of the crankshaft or camshaft are examples. A loose manifold heat control valve or endwise movement of an oil pump or distributor shaft are other examples.

Improper alignment of connecting rods is a common source of hard-to-find engine knocks. Checking and cure of this defect has been covered previously in this text.

Fan and accessory drive belts often cause noise, but the defect is readily detected. Squeaking belts can often be made quiet by the application of available special materials. In the absence of such materials a small amount of soap or talcum powder may serve.

QUIZ - ENGINE TROUBLE-SHOOTING

1-What is the principal cause of high oil consumption?

2-Name two defects, other than worn journals and bearings, that can be found by an oil pressure test.

3-Why must the crankshaft be rotated while an oil pressure test is being made?

4-An oil pressure test should be made: before an engine is disassembled---, after it has been rebuilt---.

5-Piston rings fitted too tightly in the grooves will cause excess oil consumption. True---, False---.

6-Name two ways in which overheating of an engine will cause excess oil consumption.

7-Bubbles in the coolant will interfere with proper cooling in what way?

8-What is meant by power purging of an automobile cooling system?

9-What happens if permanent type anti-freeze gets into the engine oiling system?

10-Water coming from the exhaust tail pipe is a sure indication that a cylinder head gasket is blown. True--- False---.

11-Spark plugs on an air cooled engine are sealed in the shroud. True---. False---.

12-Name four reasons for burned exhaust valves aside from defects in the valve or valve parts.

13-Name five valve and valve part defects that will cause burned valves.

14-What is the principal cause of low oil pressure?

15-A kink in the muffler tail pipe may cause engine overheating. True---, False---.

16-Name two common causes of chassis vibration.

17-How can vibration in a generator be detected?

18-Insufficient fluid in an automatic transmission may cause engine vibration. True---, False---.

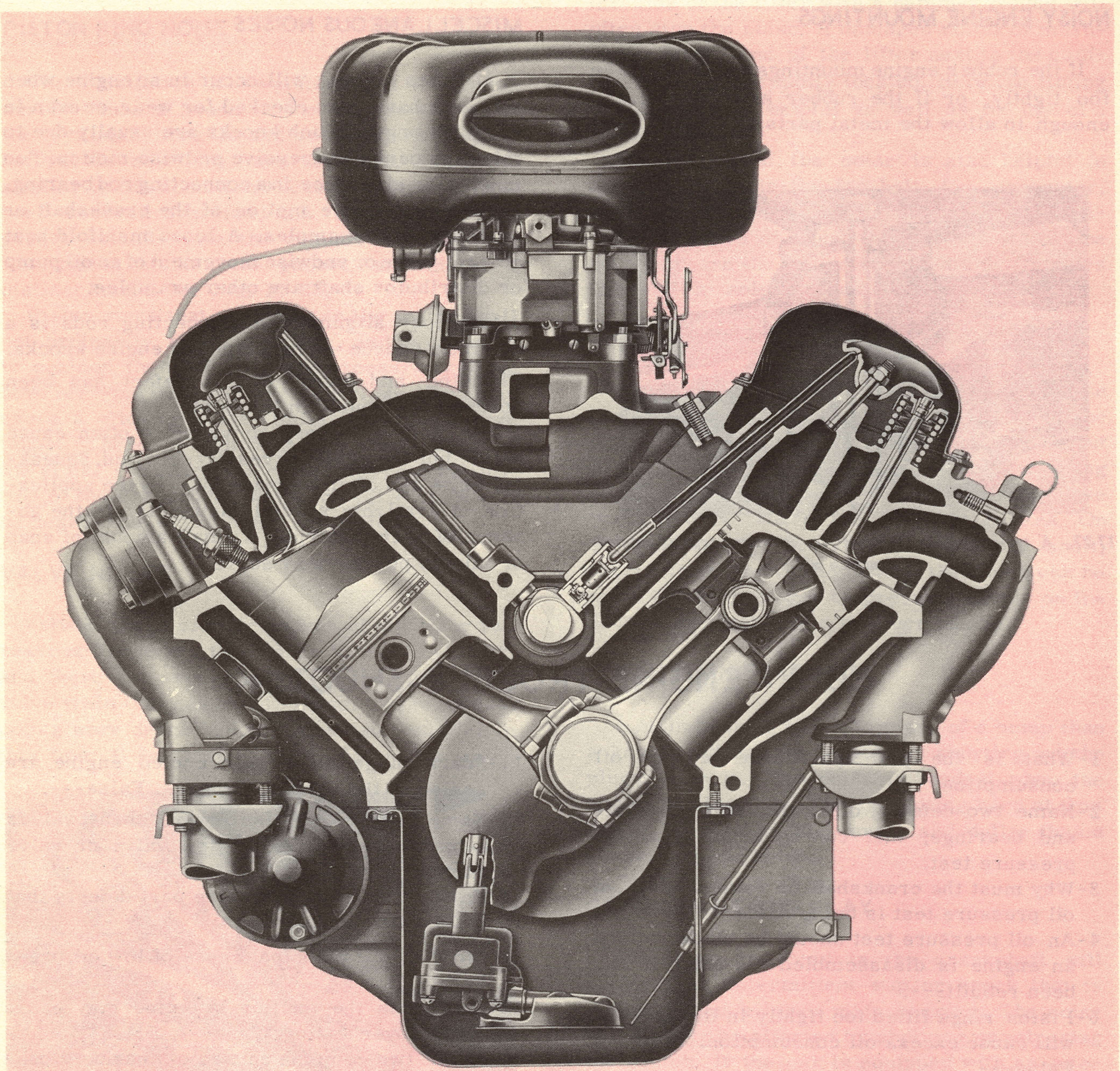
19-A slightly loose connecting rod bearing will usually knock loudest at: high speed---, medium speed---, low speed---.

20-Shorting out a spark will help locate a loose piston pin. True---, False---.

21-Shorting out a spark plug will help locate a loose flywheel. True---, False---.

22-A loose main bearing and end play in a crankshaft sound about the same. True---, False---.

23-What is a common source of knocks in a rebuilt engine?



Cross section Chevrolet Turbo-Thrust engine.

ENGINE TUNE-UP

The term "tune engine" is used and abused to such an extent that often the meaning is not quite clear. Confusion thus exists about one of the most important of all service operations.

The dictionary definition of "tune-up" as applied to machinery is:

> "To make the necessary adjustments, especially, the FINER adjustments, which are necessary to bring an engine, as an automobile or airplane engine, into FIRST-CLASS running condition."

The emphasis on "finer" and "first-class" is ours and for our purposes seems necessary.

Obviously the "finer" adjustments cannot be made to an engine wherein important defects exist. Equally obvious is the fact that these finer adjustments will have to be made before the engine is in "first-class running condition." Therefore before a "tune-up" job can even be started the engine must be checked carefully to see if it is possible to tune it up.

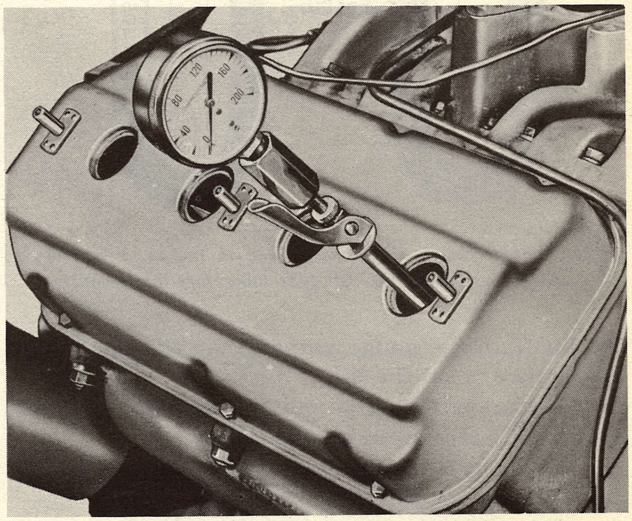
Engine tuning becomes increasingly important as engines decrease in size, while at the same time increase in power output. This amazing improvement in efficiency is due to improved design, better materials and more accurate manufacturing methods. This continued refinement of design and manufacture also entails a similar refinement of service procedures. It means closer clearances, finer fits, and more accurate adjustments.

A proper tune-up of a modern engine means splitting degrees, inches and seconds into thousandths. Obviously such accuracy can only be obtained with suitable instruments that can measure time and space to the fine degree of precision that is essential.

It should be clear that such close control cannot be had if cooling, lubrication, or other defects exist in the engine. Therefore a tune-up should not be attempted on an engine having leaking piston rings or valves, leaking or loose bearings, etc. If the radiator, water pump or cooling system is not in good condition, or if defects exist in the exhaust system, proper results simply cannot be obtained.

The first step in an engine tune-up is to make sure that EVERY ONE of the cylinders has good compression. Otherwise there is no use to proceed further. It is also important that there be no wide variation in pressure between the various cylinders. For example, if the manufacturers' specifications call for 100 lbs. compression pressure, there should be at least 90 lbs. on the weakest cylinder. A special compression pressure gauge is used for checking. See Fig. 18-1.

The check is made with all spark plugs removed, and the engine is rotated at cranking speed by means of the starting motor. The highest reading on the gauge after the engine has made several revolutions, is the accepted figure. When making the test, it is essential that the engine be at operating temperature, and that the engine oil be of the proper grade and not seriously diluted.

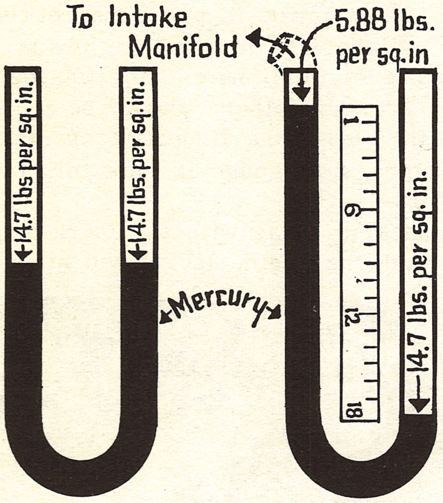


18-1. Special compression pressure gauges are needed to check the engine compression.

If the compression pressure varies more than 10 per cent between the different cylinders, it is usually assumed that the cylinders, rings or valves--or all three--are defective. Of course, if two weak cylinders are adjacent, it might indicate a blown cylinder head gasket. In any case, the cylinder head will probably have to be removed in order to remedy the defect, but it is often wise to make a further check with a vacuum gauge before the head is removed.

VACUUM GAUGE USE

When handled by an experienced operator, a vacuum gauge will provide considerable useful information about the interior condition of the engine. However, it is easy to misinterpret the readings of the instrument and reach false conclusions. In using a vacuum gauge on an engine it is much more important to note the ACTION of the gauge rather than the reading of the numbers on the dial.



18-2. *Vacuum gauge dials are marked in inches of mercury to correspond with the "U" tube laboratory instrument.*

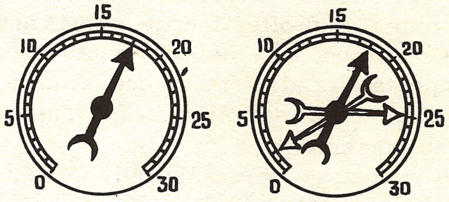
When properly used and understood, a vacuum gauge will indicate several defects:

- Incorrect carburetor adjustment
- Ignition timing errors
- Ignition defects
- Improper valve action
- Restricted exhaust system
- Cylinder leakage
- Intake system leakage

Experienced operators can break the foregoing troubles down to a finer analysis of just where the trouble lies.

If an engine is in good internal condition and running in good adjustment the vacuum gauge needle will hold steady at a reading between 17 and 21 at idling speed. There will be some variation with changes in altitude and atmospheric conditions. Every 1,000 ft. above sea level will lower the reading about one point (or one inch of mercury). See Fig. 18-2. An eight-cylinder engine will ordinarily read somewhat higher than a four.

With the engine warmed up to operating temperature and running slightly higher than at extremely low idling speed, the vacuum gauge is attached to the intake manifold. It is better to attach the hose directly to the vacuum pipe on the inlet manifold, in order to avoid any leaks that might exist in the windshield wiper or connections.



18-3. *If an engine is in good condition the hand will remain steady between 17 and 21 at sea level.*

NORMAL ENGINE

The needle will be steady between 17 and 21 while idling, will drop to below 5, then bounce up to around 25 when the throttle is suddenly opened and closed. See Fig. 18-3.

LEAKING CYLINDER RINGS

The needle may be fairly steady but will read lower than normal, perhaps 3 or 4 points. When the throttle is suddenly opened and closed, the needle may sink to zero, then bounce back to around 22. See Fig. 18-4. A compression pressure test may be necessary as a final check.

SLOW TIMING

If the compression is known to be good and the needle reads lower than it should, the ignition timing may be slow. If the reading is considerably lower than it should be, the valve timing may be slow. A check should then be made to see if either or both should be advanced.

LEAKING INTAKE

If the needle is steady but extremely low, an air leak probably exists in the carburetor, intake manifold or gaskets.

LEAKING CYLINDER HEAD

If the needle floats regularly between a low and a high reading, the cylinder head gasket is liable to be blown out between two adjacent cylinders.

CARBURETOR OUT OF ADJUSTMENT

When the needle floats slowly over a range of 4 or 5 points, a faulty carburetor adjustment is indicated.

SPARK PLUG GAPS

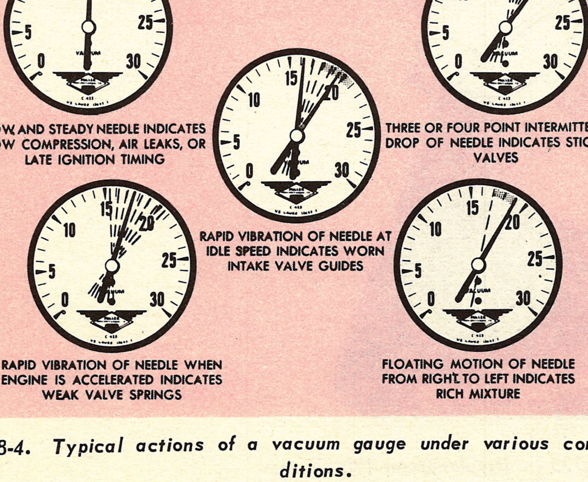
If the needle floats slowly over a narrower range--perhaps 2 points--the spark plug gaps may be spaced too close or else the ignition points not properly synchronized.

DEFECTIVE VALVE ACTION

Experience will help the operator to distinguish between the several valve troubles such as leaking, burned, sticking valves, weak valve springs and loose valve guides. The action of the needle and the range of motion are indications of which is at fault. Study of the diagram in Fig. 18-4 will be helpful. As the valve will need to be removed in most cases to remedy the defect, a check will be had on correctness of the diagnosis.

RESTRICTED EXHAUST

When the needle reads normally after the engine is first started, then sinks to zero, followed by a slow rise to below normal, the muffler may be clogged or the tail pipe kinked or plugged.


LOW AND STEADY NEEDLE INDICATES LOW COMPRESSION, AIR LEAKS, OR LATE IGNITION TIMING
THREE OR FOUR POINT INTERMITTENT DROP OF NEEDLE INDICATES STICKY VALVES
RAPID VIBRATION OF NEEDLE AT IDLE SPEED INDICATES WORN INTAKE VALVE GUIDES
RAPID VIBRATION OF NEEDLE WHEN ENGINE IS ACCELERATED INDICATES WEAK VALVE SPRINGS
FLOATING MOTION OF NEEDLE FROM RIGHT TO LEFT INDICATES RICH MIXTURE

18-4. Typical actions of a vacuum gauge under various conditions.

ENGINE MECHANICAL CONDITION

If the vacuum gauge indicates loss of compression or improper valve action as described, it is futile to try to proceed with a tune-up until the faults are corrected. If however the tests indicate timing errors, intake leaks, carburetor out of adjustment or a restricted exhaust system--the remedy for each of which is obvious--it will be in order to correct these defects as the next step.

Much of the tune-up work is concerned with the ignition system, particularly the spark plugs, timing, distributor points and condenser. This is a complete subject in itself and is covered completely in the electrical section of this text.

COMBUSTION ANALYZERS

The last step of an engine tune-up is usually the final adjustment of the carburetor. This is often facilitated by the use of an exhaust gas analyzer which measures the mixture supplied by the carburetor. With the aid of this instrument it is possible to adjust the mixture to obtain maximum power and mileage from the gasoline.

This is important as an engine may apparently run well when the mixture is too rich or too lean. An over-rich mixture is wasteful, tends to form soot in the engine and exhaust system and promotes crankcase dilution of the engine oil. Mixtures that are too lean cause loss of power, cause "flat spots" in acceleration and tend to cause burned valves and spark plugs.

The subject of mixtures, combustion and combustion analysis is covered fully in the carburetor section of this text. Dynamometers are also used extensively in tune-up work. These were described and illustrated earlier in this text.

HIGH SPEED TUNING

Engine tuning is carried to extremes when it is desired to obtain the maximum speed and power out of an engine. This procedure often involves extensive mechanical alteration of the engine such as porting and relieving the cylinder block, increasing the compression ratio, enlarging the valves, altering the bore and stroke of the engine, installing special custom made faster camshafts, increasing the valve lift, etc.

Intake and exhaust manifolds are increased in size and streamlined, multiple carburetors or fuel injectors installed, valve and ignition timing altered, etc. This is a complete and complicated subject in itself and is not within the scope of this text.

QUIZ - ENGINE TUNE-UP

1-What is the first step to be taken in an engine tune-up?

2-How much variation in compression pressure is permissible between the cylinders of a V-8 engine? 10%---, 15%---, 20%---.

3-Name five engine defects that can be discovered by the use of a vacuum gauge.

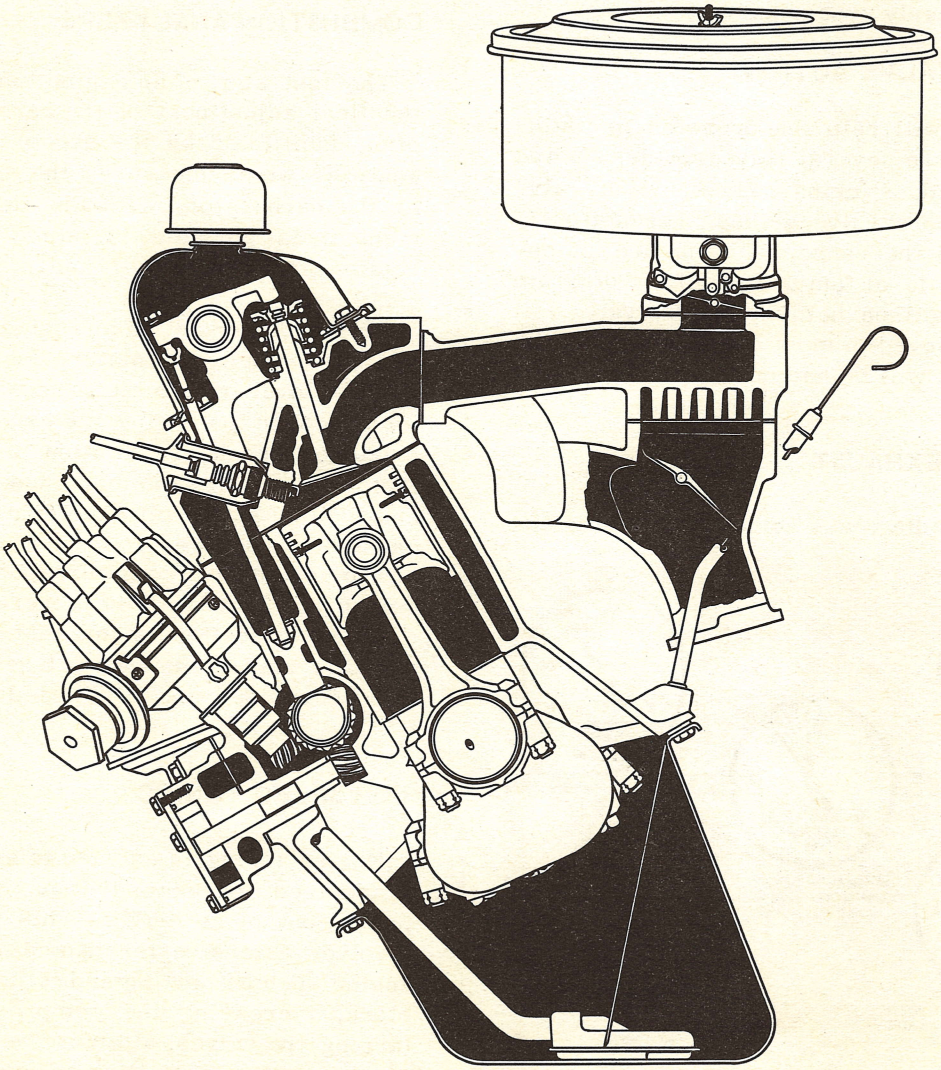
4-At an elevation of 5,000 ft. above sea level, an engine in good condition will give a vacuum gauge reading of 12-17---, 17-21---, 21-26---.

5-If the vacuum gauge needle is steady, but the reading extremely low, the trouble is liable to be: carburetor out of adjustment---, leaking piston rings---, air leak in intake system---.

6-When the needle floats slowly over a range of 4 or 5 points, the ignition timing is slow. True---, false---.

7-An engine may run well with the carburetor improperly adjusted. True---, false---.

8-What is usually the last step in an engine tune-up procedure?



Dodge Lancer engine. Bore 3.40 in. Stroke 3.125 in. Displacement 170 cu. in.

AUTO SHOP SAFETY

Safety is everyone's responsibility. It cannot be left to a committee or a few individuals, but everyone must always be on the alert so that he is not the cause of an accident to himself or any of his fellow workers.

One of the basic rules of safety in any shop is proper and correct conduct of every individual. There can be no running, no practical jokes, no horseplay. Such conduct invariably results in accidents as well as distracting the others in the shop from the work they are supposed to do.

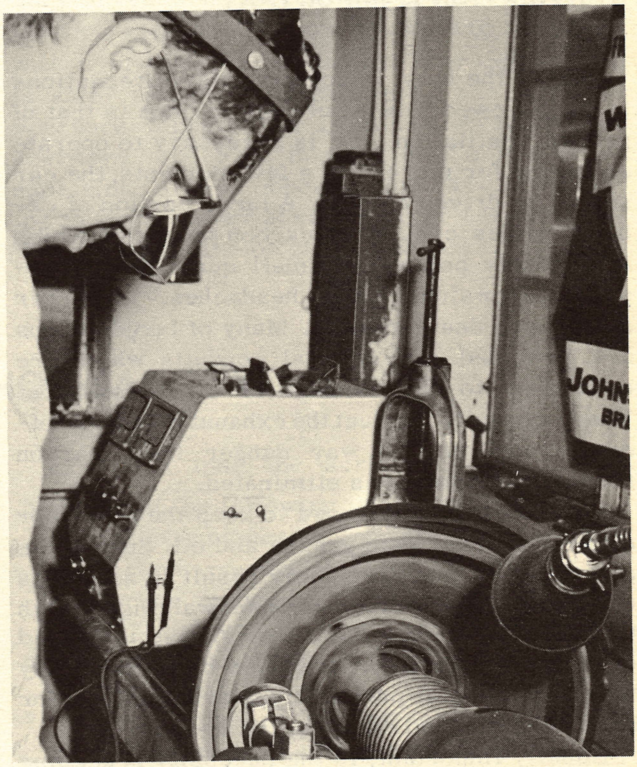
Because of the many combustibles, such as gasoline, lacquer thinner and certain cleaning fluids used in automobile repair shops, special precautions are needed to prevent fire. Fuel, thinner and other combustibles should always be kept in closed containers designed for the purpose. This will not only help prevent fire but also the evaporation of the chemicals with attendant loss of profits. Painting should be done in paint spray booths provided with exhaust fans and conforming to underwriters requirements. Smoking and unshielded flames should never be permitted. No smoking signs, Fig. 19-1, should be prominently displayed.

19-1. "No Smoking" signs are displayed in the interests of safety. They should be obeyed.

All shops should be provided with an ample number of fire extinguishers. Everyone should be familiar with their location. Remember that water cannot be used to extinguish a gasoline or grease fire. For such fires, carbon tetrachloride, foam or if nothing else is available, sand can be used.

As a further protection against fire, oil and paint rags should be kept in suitable containers. Care must always be exercised so that spontaneous combustion does not occur.

Painters should always use masks when spraying paint as a guard against respiratory illnesses resulting from the inhalation of paint fumes. Mechanics when using grinding wheels, sanders or when chipping metal should wear goggles as a protection for the eyes, Fig. 19-2. These should also be used when using compressed air to blow dirt from parts.



19-2. Protective goggles or eye shield should be worn during grinding operations or other jobs when there is a possibility of injury to the eyes.

Special safety precautions are also necessary when working on automotive electrical circuits. Unless the starting battery is needed for making tests of the circuit, it should be disconnected to eliminate the possibility of any short circuits and attendant possibility of fire or damage to the circuit and tools. Most important, a naked flame should not be used to observe the level of the electrolyte in the starting battery. Acid fumes are highly explosive and acid would be splashed into the mechanics eyes. When it becomes necessary to note the electrolyte level a flash light should be used, Fig. 19-3.

Special care must be observed when removing the cap from an automotive radiator. The cooling system on the modern automobile is under pressure and the sudden removal of the radiator cap will cause the superheated steam and water to be forced out. This will cause severe burns. When removing a radiator cap, it should be covered with a cloth and given a half turn. Then after the steam has escaped and the pressure reduced, the cap can be removed completely without any danger to the mechanic.

VENTILATION IS IMPORTANT

One of the most important safety precautions to be followed in any automotive shop is that of proper ventilation. If it is necessary to operate an engine for more than a few moments, the car should be driven outside. A large portion of exhaust fumes consist of carbon monoxide which is a deadly poison. In small quantities it produces drowsiness and headaches. In larger quantities, death results. Many of larger shops are provided with special conduits which are connected to the exhaust of the automobile. These conduits conduct the exhaust gases out-of-doors and in that way danger from carbon monoxide poisoning is eliminated.

Care must be exercised to keep the shop floor clean and free from grease and oil. Such spots are slippery and frequently result in accidents to mechanics and other persons walking through the shop. Whenever any oil or grease is spilled or drips on the floor, it should be immediately wiped up. Special preparations are available for absorbing oil, and cleaning the spots.

Equally important, is the necessity of keeping the floor clear of tools and parts. When laid in the aisle, there is always the possibility of someone tripping on them. A similar condition results from a jack handle sticking out into the aisles where it may cause someone to fall. If lifts are not available, and it is necessary to keep the car raised for a protracted period, the car should be placed on horses or stands. In that way there will be no chance of the car falling as the result of a faulty jack. In addition such practice frees the jack for work on other vehicles.

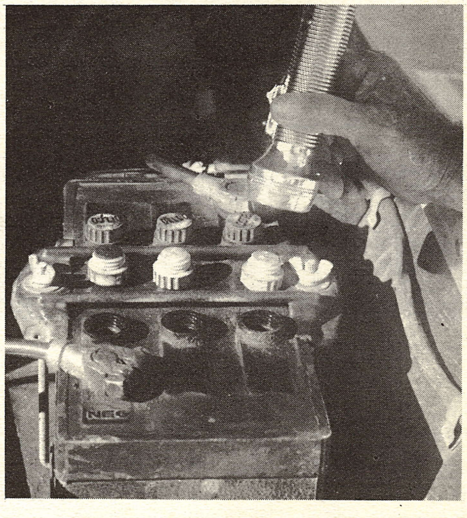
There are also many safety precautions to be followed in the use of tools.

USING TOOLS SAFELY

Files should never be used without a handle as there is always the danger of running the pointed tang into the palm of the hand. Neither should files be used as pry bars, nor should they be hammered. Files are made with hard temper and consequently are quite brittle and when hammered, small pieces may fly off and cause severe wounds or loss of eyesight. Hardened surfaces such as the face of an anvil should not be struck with a hammer as bits of steel may fly off and cause damage. Further in connection with hammers and sledges, care must always be exercised that the head is always securely attached to the handle. Loose hammer and sledge heads may fly off when the tool is used and anyone standing in the way will be struck and severely injured.

When the head of a chisel becomes swagged over, it should be discarded or reground to remove the swagged edges. This will prevent bits of steel from flying off and causing damage.

Whenever grinding is done, the mechanic should wear goggles to protect his eyes. The grinding wheel should always be provided with a protecting guard. The reason for the guard is that in the event of the grinding wheel bursting due to centrifugal force, the danger to the operator will be minimized. Unless the grinding



19-3. The fumes from starting batteries are highly explosive. Use a flash light when checking the level of the electrolyte.

wheel is designed to take such strains, its side surfaces should not be used for grinding.

As there is always a possibility of a driving belt breaking or a rotating wheel bursting, it is always advisable to stand away from the plane of rotating parts. In the event of any such breakage, parts will be hurled with teriffic force and anyone standing in line with the rotating part may be severely injured.

When using a wrench, there is less danger to the mechanic if he pulls on the handle, rather than pushes on it. In that way, should the wrench slip, there will be less danger of skinning the knuckles. Further in that connection, when the jaws of a wrench become worn or sprung, the wrench should be discarded, as it will no longer fit the nut securely and will tend to slip.

Compressed air is an important "tool" in every shop. The air gun should not be pointed at anyone. The high pressure of the air can blow dirt and dust particles at such high speed that they will puncture the skin, and get into the eyes.

When changing large size truck tires, which have a detachable ring to secure the tire to the rim, do not lean over the tire while it is being inflated. These rings have been blown off the rim by the force of the compressed air and the mechanic severely injured.

Care must always be exercised, when working around any machinery, engine or motor that there is no chance of loose clothing being caught and entangled in rotating parts. For that reason, it is advisable to tuck neckties within the shirt. If long sleeves are being worn, these should be buttoned at the cuff. Caps without brims are considered safer than those with brims, because of the possibility of the protruding brim being caught in some rotating part.

In regard to safety precautions when using oxygen and acetylene for welding there are many points to observe. Never allow oil or grease to contact oxygen under pressure. Do not lubricate welding and cutting apparatus. Never use oxygen as a substitute for compressed air, as a source of pressure, or for ventilation. Before starting to weld or cut, make sure that flame, sparks, hot slag, or hot metal will not be likely to start a fire. Always wear goggles when working with a lighted blowpipe.

Be sure to keep a clear space between the cylinders and the work as you may find it necessary to reach and adjust the regulators quickly. Do not risk hand burns by lighting the torch with a match. Use a friction type lighter as it is safer and also easier. Never use acetylene pressure higher than 15 p.s.i. Never release acetylene where it might cause a fire or an explosion. Always check equipment before starting to work. Never braze, weld or use acetylene flame on gasoline or other fuel tanks.

QUIZ - AUTO SHOP SAFETY

1-Why are running and practical jokes prohibited in shops?

2-Why should a mask be worn while spraying paint?

3-Starting batteries should always remain connected in the circuit while working on the electrical system. True_____False_____

4-What happens when a file is used as a pry bar?

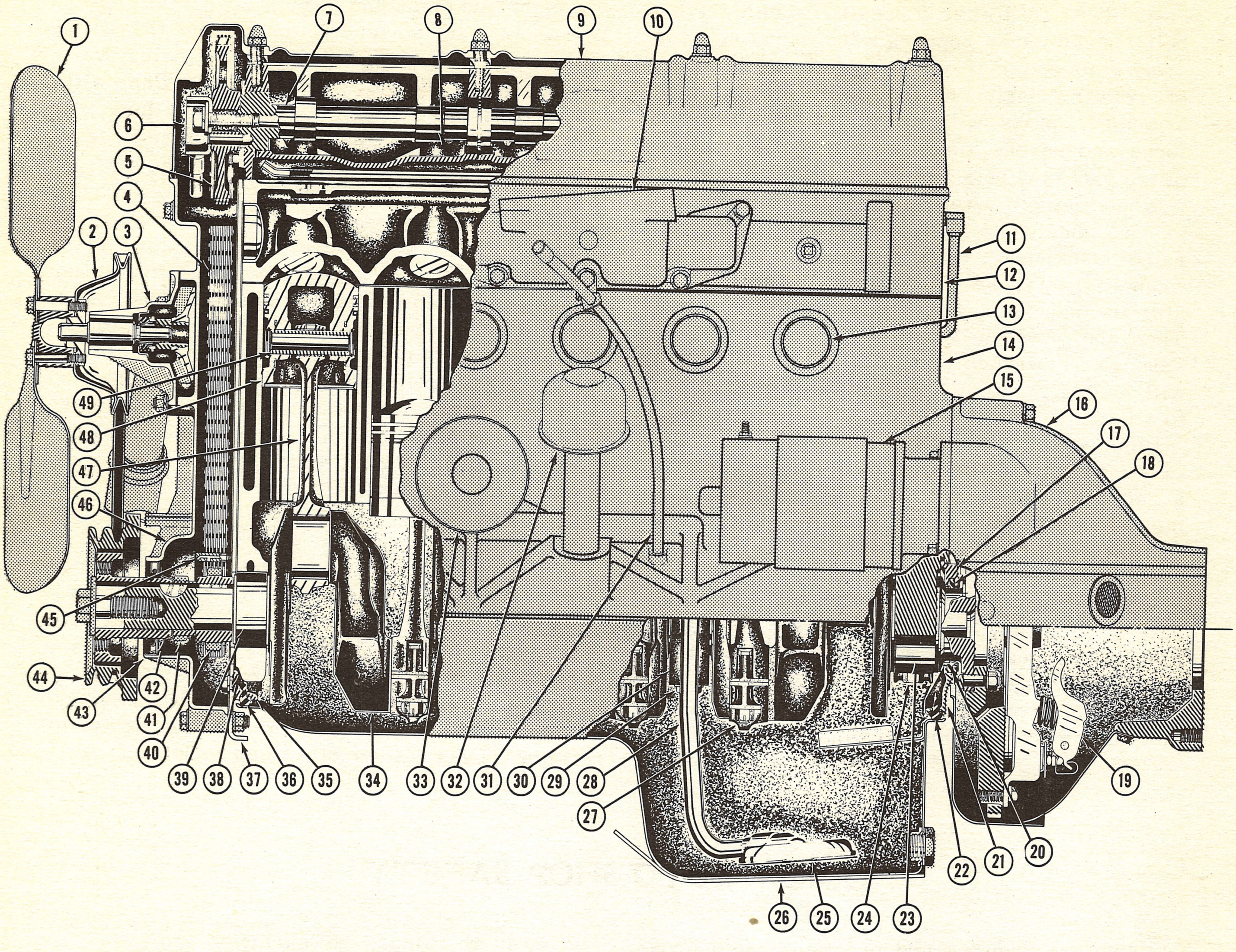
- a. It bends
- b. It breaks
- c. It will mar the surfaces

5-Which of the following is correct?

- a. Carbon monoxide is used in welding
- b. Carbon monoxide is a deadly poison
- c. Carbon monoxide is used to inflate tires on race cars

6-Why is it dangerous to stand in the plane of a rotating part?

7-Oxygen fittings on welding equipment should be well lubricated with mineral oil. True_____ False_____



19-4. Side sectional view, Jeep Tornado-OHC engine with parts identified. 1-Cooling fan, 2-Fan drive pulley, 3-Water pump, 4-Timing chain, 5-Camshaft sprocket, 6-Fuel pump eccentric, 7-Camshaft, 8-Cam bearing support deck, 9-Rocker arm cover, 10-Intake manifold, 11-Lubrication tube, 12-Cylinder head, 13-Core plug, 14-Cylinder block, 15-Starting motor, 16-Clutch housing, 17-Filler block guard, 18-Upper rear oil seal, 19-Clutch, 20-Lower rear oil seal, 21-Rear filler block, 22-Oil pan seal, 23-Rear main bearing, 24-Rear main bearing cap, 25-Oil intake screen, 26-Oil pan, 27-Connecting rod bearing cap, 28-Oil intake pipe, 29-Intermediate main bearing cap screw, 30-Intermediate main bearing cap, 31-Dip stick guide, 32-Breather cap, 33-Oil filter, 34-Crankshaft, 35-Front filler block, 36-Oil pan seal, 37-Front engine plate, 38-Front main bearing cap, 39-Front main bearing, 40-Timing chain sprocket, 41-Oil pump drive gear, 42-Oil slinger, 43-Timing chain cover oil seal, 44-Vibration damper, 45-Oil fitting, 46-Timing chain cover, 47-Connecting rod, 48-Piston, 49-Piston pin.

AUTOMOTIVE FUELS

The fuel used in most automobiles and internal combustion engines is gasoline. Other fuels include methanol, benzol, alcohol, alcohol-gasoline blends, and liquid petroleum gas.

Gasoline is a colorless liquid obtained from crude petroleum, as a result of a complicated distillation and cracking process. Two important characteristics of gasoline as used for fuel in automotive engines are volatility, and anti-knock characteristics.

The volatility of any liquid is its vaporizing ability. In the case of a simple substance, it is usually determined by its boiling point. For example, the boiling point of water is 212 deg. F. Gasoline is a mixture of hydrocarbon compounds each having its own boiling point. Gasoline as used for motor fuel therefore has a range of boiling points extending from approximately 100 deg. F. up to 400 deg. F.

The fuel must remain a liquid until it enters the air stream in the carburetor throat. At this time, it must quickly vaporize and mix uniformly in the correct proportions with the intake air.

The volatility of gasoline affects ease of starting, length of warming up period, and engine performance during normal operation. For easy starting with a cold engine, the fuel must be highly volatile. In other words, it must vaporize easily. Therefore when cold weather approaches, fuel refiners increase the percentage of highly volatile fuel contained in gasoline, to insure easier starting under the cold weather operating conditions.

If the percentage of volatile fuel is too high, a condition known as vapor lock occurs. Vapor lock results from fuel vaporizing in the fuel line, fuel pump, or in the carburetor before the fuel is actually discharged from the jet. As a result of vapor lock, the engine is starved for fuel, and will stop running. This is not an unusual occurrence, particularly in the springtime before the refiners have reduced the percentage of highly volatile fuel in the gasoline.

In addition to the highly volatile fuel needed for easy starting, fuel not quite so volatile is required for quick warm-up.

A portion of the fuel must also be sufficiently volatile to insure proper vaporization during periods of acceleration. If fuel as sprayed from the accelerating pump jet does not vaporize readily, it will result in a lean mixture which would exist only for a moment, but which is known as a "flat-spot."

For maximum power and economy of operation, fuel with a lower volatility but high heat content is required.

When weather conditions or overchoking, or a over-rich mixture caused by any condition leaves an excessive amount of fuel unvaporized, the unvaporized fuel seeps by the piston and piston rings into the crankcase. This dilutes the lubricating oil, reduces its lubricating qualities, and tends to form sludge and deposit varnish on the pistons and rings.

Petroleum contains many impurities that must be removed during the refining process before gasoline suitable for automotive use is produced. At one time, considerable corrosion was caused by the sulfur contained in petroleum products. However, modern refining procedure has greatly eliminated that problem. Another difficulty was the tendency for the hydrocarbons in gasoline to oxidize into a sticky gum when exposed to air. This resulted in clogged carburetor passages, stuck engine valves and excessive deposits in the combustion chamber. Chemicals that control the gumming tendency are now added to gasoline.

ANTI-KNOCK QUALITIES

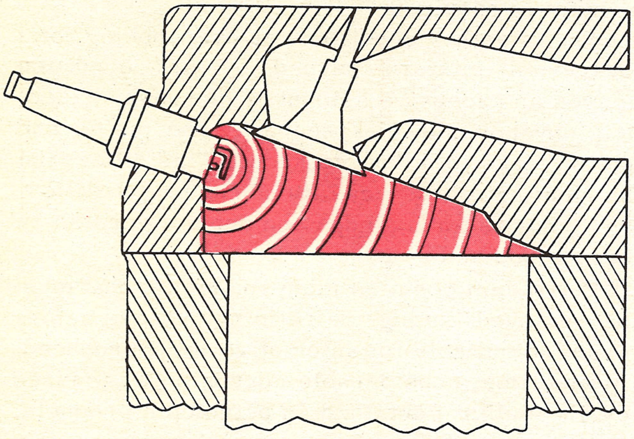
One of the most important qualities of modern fuel is the ability to burn without causing detonation or knocking. The tendency toward detonation is overcome by the addition to the fuel of such compounds as tetraethyl lead. In addition, refining processes also aid materially in producing knock-free gasoline.

To understand what is meant by anti-knock quality, it is necessary to understand the process of combustion.

When substance burns, it is actually uniting in rapid chemical reaction with oxygen, which is one of the constituents of air. During the burning process, the molecules of the substance and oxygen are set into very rapid motion and heat is produced. In the combustion chamber of an engine cylinder, the gasoline vapor and oxygen in the air are united and burned. They combine, and the molecules begin to move about very rapidly as the high temperatures of combustion are reached. The molecules bombard the combustion chamber walls, and the head of the piston with a rain of fast-moving molecules. It is this bombardment that causes the heavy push on the piston, and forces it downward on the power stroke.

NORMAL COMBUSTION

The normal combustion process in the combustion chamber, Fig. 20-1, goes through three stages that are sometimes termed formation or nucleus of flame, hatching out, and propagation.



20-1. Normal process of combustion. Compare with Fig. 20-2 and 20-3.

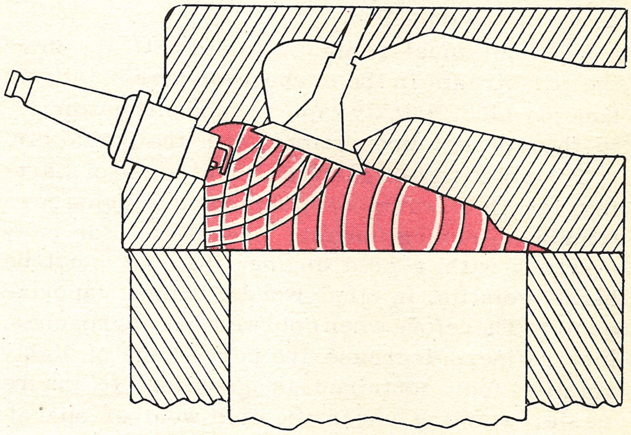
As soon as the ignition spark jumps the gap of the spark plug, a small ball of blue flame develops in the gap. This ball is the first stage or nucleus of the flame. It enlarges with relative slowness, and during its growth there is no measureable pressure created by the heat.

As the nucleus enlarges, it develops into the hatching-out stage. The nucleus is torn apart so that it sends fingers of flame into the mixture in the combustion chamber. This causes enough heat to give a slight rise in temperature and pressure in the entire fuel-air mixture. Consequently a lag still exists in the attempt to raise pressure in the entire cylinder.

It is during the third stage or propagation, that the effective burning of the fuel takes place. The flame burns in a front which sweeps across the combustion chamber, burning rapidly and causing great heat with its accompanying rise in pressure. It is this pressure which causes the piston to move downward. During normal combustion, the burning is progressive. It increases gradually during the first two stages, but during the third stage the flame is extremely strong as it sweeps through the combustion chamber. However, there is no violent or explosive action such as when detonation, ordinarily responsible for pinging or knocking, occurs.

DETONATION

If detonation takes place it occurs during the third stage of combustion, Fig. 20-2. As was pointed out, in the propagation stage flame sweeps from the area around the spark plug toward the walls of the combustion chamber. Parts of the chamber the flame has passed may contain inert non-burnable gases, but the section not yet touched by flame contains highly compressed heated combustible gasses. As the flame races through the combustion chamber, the unburned gases, ahead of it are still further compressed and are heated to higher temperatures. Under certain conditions the extreme heating of the unburned part of the mixture may cause it to ignite spontaneously and explode. It is this rapid uncontrolled burning in the final stage of combustion which is called detonation. It is caused by the rapidly burning flame front compressing the unburned part of the mixture to



DETONATION

20-2. When detonation occurs, unburned gases are compressed ahead of the flame front, raising their pressure and temperature so that it is ignited.

the point of self ignition. This secondary wave front collides with the normal flame front and makes an audible knock or pinging sound.

Detonation may harm an engine or hinder its performance in several ways. In extreme cases pistons have been shattered, cylinders burst, or cylinder heads cracked. At times these temperatures resulting from detonation may reach the point where the piston is actually melted. Other effects of detonation may be overheating of the engine, broken spark plugs, overloaded bearings, high fuel consumption, loss of power, etc.

OCTANE RATING

The ability of a fuel to resist detonation is measured by its octane rating. The octane rating of a fuel is determined by matching it against mixtures of normal heptane and iso-octane in a test engine under specified test conditions, until a mixture of these pure hydrocarbons is found which gives the same degree of knocking in the engine as the gasoline being tested. The octane number of the fuel is then the per cent of the iso-octane in the matching iso-octane normal-heptane mixture. For example, a gasoline rating of 90 octane is equivalent in its knocking characteristics, to a mixture of 90 per cent iso-octane and 10 per cent normal heptane.

The tendency of a fuel to detonate varies in different engines, and also in the same engine under different operating conditions. The shape of the combustion chamber is an important factor, but most important of all is the compression ratio. It is important to emphasize that octane number of a fuel has nothing to do with its starting qualities, power, volatility or other major characteristics. If an engine operates satisfactorily with a fuel of a certain octane rating, its performance will not be improved by using fuel of a still higher octane rating.

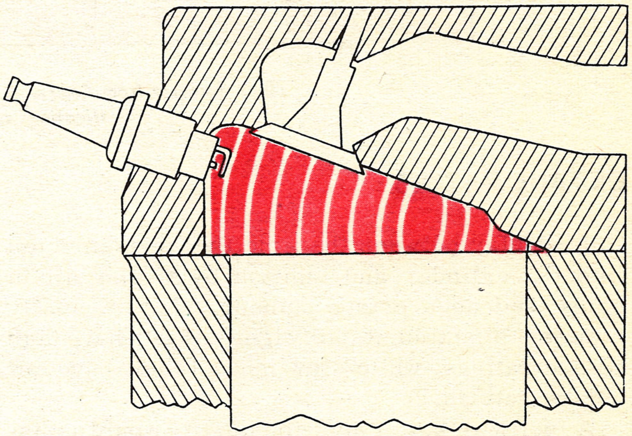
FUEL ADDITIVES

Tetraethyl lead is the most popular compound added to fuel to suppress knocking. In addition to additives used to suppress the detonation, some fuels also contain additives designed to reduce the accumulation of deposits in the combustion chamber, and to absorb any moisture which may condense in the fuel. Still another additive is provided to lubricate the valve stems, and the upper area of the cylinder wall. Detonation is not to be confused with preignition. Detonation takes place late in the burning process after the spark has occurred. Preignition, Fig. 20-3, however, is an igniting of the fuel-air mixture during compression, before the spark has occurred as caused by some form of hot spots within the cylinder.

DIESEL FUELS

The type of fuel available for use in Diesels varies from highly volatile jet fuels and kerosene, to the heavier furnace oil. Automotive Diesel engines are capable of burning a wide range of fuel between these two extremes. How well a Diesel engine can operate with different types of fuel, is dependent upon engine operating conditions, as well as fuel characteristics.

A large variety of fuel oils are marketed for Diesel engine use, by the petroleum industry. Their properties depend on the refining practices employed, and the nature of the crude oil from which they are produced. Fuel oils, for example, may be produced within the boiling range of 300 to 750 deg. F. having many possible combinations of other properties. The classification of commercially available fuel oils that has been set up by the American Society for Testing Materials is shown in Fig. 20-4. Grade 1D fuels range from kerosene to what is called intermediate distillates. Grades 2D, and 4D, each have progressively higher boiling points, and contain more impurities.



20-3. Preignition is the igniting of the fuel mixture, before the spark occurs.

The fuels commonly known as high-grade fuels, kerosene and 1D fuels, contribute a minimum amount to the formation of harmful engine deposits and corrosion. There are less impurities present in those fuels, and therefore the tendency for such action to take place is kept to a minimum.

While refining removes the impurities it also lowers the heat value of the fuel. As a result, the higher grade fuels develop slightly less power than the same quantity of low-grade fuel. However this is usually more than offset by other maintenance advantages. Some Diesel fuel systems undergo modification to form what are classified as jet fuels.

existing engine temperature.

For engines operating at reduced speed and load, or in cold weather, lower boiling point fuels will give more satisfactory performance. Fuels that cannot be completely vaporized and burned will accumulate and form sludge and other harmful deposits in the engine.

ASTM DIESEL FUEL CLASSIFICATION D075-49T

Grade of Diesel Fuel Oil	Cetane Number (Min.)	Sulfur % by Wt. (Max.)	Distillation Temperatures, °F		Viscosity at 100° F Kinematic Centistokes (or SUS)	
			90% Boiling Point (Max.)	100% Boiling Point (Max.)	(Min.)	(Max.)
No. 1-D	40	0.50		625	1.4	
No. 2-D	40	1.0	675		1.8 (32.0)	5.8 (45)
No. 4-D	30	2.0			5.8 (45)	26.4 (125)

20-4. Excerpt from American Society of Testing Materials specifications for Diesel fuels.

CETANE RATING

The delay between the time the fuel is injected into the cylinder and ignition by the hot air is expressed as a cetane number. This is usually between 30 and 60. Rapidly ignited fuels have high cetane ratings, while slow ignited fuels have low cetane ratings.

A fuel with better ignition quality would assist combustion more than a lower cetane fuel during starting and idling conditions when compression temperatures are cooler. For that reason, ether with a very high cetane rating of 85-96, is often used for starting Diesel engines in cold weather. The lower the temperature of the surrounding air, the greater the need for fuel that will ignite rapidly.

When the cetane number of the fuel is too low, it may result in difficult starting, engine knock and puffs of white exhaust smoke, particularly during engine warm-up and light load operation. If such conditions continue, harmful engine deposits will accumulate in the combustion chamber.

BOILING RANGE

The boiling temperature of fuel is also the temperature at which it is completely vaporized. Furthermore, fuel can be completely burned in an engine only in vaporized form. Because of this, the boiling range of fuel oil should be low enough to permit complete vaporization at the

SULFUR CONTENT

Sulfur content in fuel oil should be as low as possible in order to keep the amount of corrosion and deposit formation at a minimum. Tests have shown that increasing sulfur content from .25 to 1.25 per cent increases deposits and wear 135 per cent.

LIQUEFIED PETROLEUM GAS

A mixture of gaseous petroleum compounds, principally butane and propane, together with smaller quantities of similar gases, is known as liquefied petroleum gas. This is frequently abbreviated as LPG or LP gas.

Liquefied petroleum gas is used as fuel for internal combustion engines, principally in the truck and farm tractor fields.

Chemically, LPG is similar to gasoline as it consists of a mixture of compounds of hydrogen and carbon. However, it is a great deal more volatile, and at usual atmospheric temperatures it is a vapor. For that reason, when used as a fuel for internal combustion engines, a special type of carburetor is required.

For storing and transporting LPG, it is compressed and cooled so that it is a liquid, and depending upon conditions; approximately 250 gallons of LPG are compressed into one gallon of liquid. Because of the pressure it must be stored in strong tanks. The boiling point of propane is approximately 44 deg. F. below zero.

At temperatures below their boiling points, butane and propane exert no pressure, but as the temperature increases, the pressure increases rapidly. For example, at 40 deg. F., liquid propane will have a pressure of 65 lb., while butane will have a pressure of about 3 lb. At 65 deg. F., the pressure of propane will have increased to 100 lb. and butane to 15 lb.

LPG gas is made of surplus material in the oil fields, and is becoming more widely distributed as an increasing number of trucks and tractors are being fitted with the equipment necessary to use it.

In addition to its low cost, LPG has the advantage of having a high octane value. Pure butane has a rating of 93 octane while propane is approximately 100. The octane rating of LPG will range between these two values, depending upon the proportion of each gas used.

As it is a dry gas, LPG does not create carbon in an engine, and does not cause dilution of the engine oil. As a result, maintenance and parts replacement on engines is reduced. In addition, oil changes for the engine can be made at less frequent intervals, because it is such a clean-burning fuel.

Other advantages claimed for LPG are easy cold weather starting, lack of objectionable exhaust odor and elimination of evaporation.

ALCOHOL

Alcohol is sometimes used as fuel for automotive internal combustion engines. It is a distillate of wood or grain, and has a relatively high octane rating.

Alcohol is frequently used as an additive to commercial gasoline, and in that way will absorb any condensed moisture which may collect in the fuel system.

Water will not pass through the filters which are placed in the fuel line, and consequently when any water collects it will prevent the free passage of fuel. In addition, water will tend to attack or corrode the zinc die castings of which many carburetors and fuel pumps are made. This corrosion will not only destroy the parts but also will clog the system, preventing the flow of fuel. By using alcohol in gasoline, any water present will be absorbed and will then pass through the fuel filters and carburetor jets, and into the combustion chamber.

Alcohol is frequently used in combination with benzol as a fuel for race engines.

BENZOL

Benzol is a volatile liquid hydrocarbon obtained in the refinement of coal tar. It has a high octane value, and is used occasionally to blend with gasoline to increase its octane value, and is also used in combination with alcohol for race car engines.

HEAT VALUE

The power obtained from any fuel is determined by its heat value. This is measured by burning a unit amount of fuel in an excess of air or oxygen, and is measured in British Thermal Units per pound of fuel. One British Thermal Unit (B.T.U.) is the amount of heat required to raise one pound of water from 39 deg. to 40 deg. F. One B.T.U. is equal to 778.6 foot-pounds.

Higher Heat Values of Hydrocarbon Found in Gasoline:

Hexane	20700
Octane	20500
Monane	20450
Heptane	20600
Dodecane	20350
Undecane	20375
Dicane	20420

COMBUSTION OF GASOLINE

The rapid combination of fuel with oxygen producing heat, is known as combustion. In the case of gasoline, it is the rapid oxidation of the carbon and the hydrogen constituting the fuel. The heat produced is the result of the chemical change. The chemical equation of combustion for octane is:

$$C_8H_{18} + 12.5\ O_2 = 8\ CO_2 + 9\ H_20$$

In this equation, C_8H_{18} represents the chemical formula for gasoline, and the 12.5 O_2 is the oxygen which is required to burn one part of gasoline. This produces eight parts of carbon dioxide (CO_2) and nine parts of water (H_2O).

However, in actual operation of an engine instead of pure oxygen, air is used, which consists of a mixture of 1/5 oxygen and 4/5 nitrogen, by volume. From the standpoint of weight, it consists of one part oxygen, and 3 1/2 parts of nitrogen, or more exactly 23 parts of oxygen, and 77 parts of nitrogen.

The atomic weights for the different elements entering into the combustion of octane and air are as follows:

Carbon	12
Nitrogen	14
Oxygen	16
Hydrogen	1

On a weight basis, the chemical formula of combustion is:

$$114\ C_8H_{18} + 400\ O_2 = 352\ CO_2 + 162\ H_2O$$

As air is a mixture of oxygen and nitrogen in a ratio of 23 to 77, the nitrogen must also be considered in writing the combustion equation for octane and air. The amount of nitrogen present with 400 weight units of oxygen is

$$400 \times \frac{77}{23} = 1339$$

This nitrogen is present in the combustible mixture and also in the products of combustion. It must therefore be added to both sides of the equation:

$$114\ C_8H_{18} + 400\ O_2 + 1339\ N_2 = 352\ CO_2 + 162\ H_2O + 1339\ N_2.$$

For one pound of octane the formula becomes:

$$3.09 \text{ lb. } CO_2 + 1.42 \text{ lb. } H_2O + 11.76 \text{ lb. } N_2$$

or 1 lb. of fuel + 15.27 lb. air = 16.27 lb. of exhaust gas.

The amount of power developed in an internal combustion engine is dependent on the heat that can be obtained from burning the fuel. This in the case of gasoline or any of the hydrocarbons, is equal to the total of the heats due to the combustion of the carbon and hydrogen. From that must be subtracted the heat required to break up the hydrocarbon molecules.

When carbon becomes carbon dioxide, due to combustion, 14,542 B.T.U. are liberated for each pound of carbon burned. In the combustion of hydrogen to steam, 62,032 B.T.U. are liberated for each pound of hydrogen. To break up the octane into carbon and hydrogen, 1,523 B.T.U. are required for each pound of octane.

In octane (C_8H_{18}) the carbon is 84.2 per cent while the hydrogen is 15.8 per cent. The heat produced by the combustion is:

84.2 per cent of 14,542 B.T.U. = 12,244
15.8 per cent of 62,032 B.T.U. = 9,801

making a total of 22,045 B.T.U. From this must be subtracted 1,523 B.T.U. required to break up the fuel into carbon and hydrogen. The total heat from burning one pound of octane is therefore 20,522 B.T.U.

COMBUSTION CHAMBER TEMPERATURE

Temperatures in the combustion chamber reached through the combustion of fuel vary through a relatively wide range. These temperatures are affected by compression ratio, combustion chamber contours, the effectiveness of the cooling system, the richness of the combustible mixture, and also the amount of burned gases that have remained in the cylinder from the previous cycle.

At the end of the compression stroke, but before ignition, temperatures of approximately 1500 deg. F. may be considered as average for an engine with a compression ratio of 9 to 1.

Immediately after ignition, the temperature increases very rapidly and will reach a value of approximately 5500 deg. F.

QUIZ - AUTOMOTIVE FUELS

1-Name three different fuels used in internal combustion engines.

2-The volatility of gasoline is equivalent to its:
  a. Octane rating
  b. Boiling point
  c. Cetane rating
  d. Distillation

3-What characteristic of fuel affects easy starting?

4-Name the three stages of normal fuel combustion in an internal combustion engine.

5-Describe detonation.

6-Describe preignition.

7-Octane and what other material are used to determine the octane rating of a fuel?
  a. Cetane
  b. Propane
  c. Heptane
  d. Benzol

8-Alcohol is added to gasoline primarily to:
  a. Provide easier starting
  b. Absorb any moisture that may be present
  c. Increase the volatility of the fuel

9-Automotive Diesel engines are capable of burning a wide range of fuels. True_____ False_____.

10-Cetane number of a Diesel fuel is a measure of:
  a. Volatility
  b. Viscosity
  c. Time between fuel injection and ignition

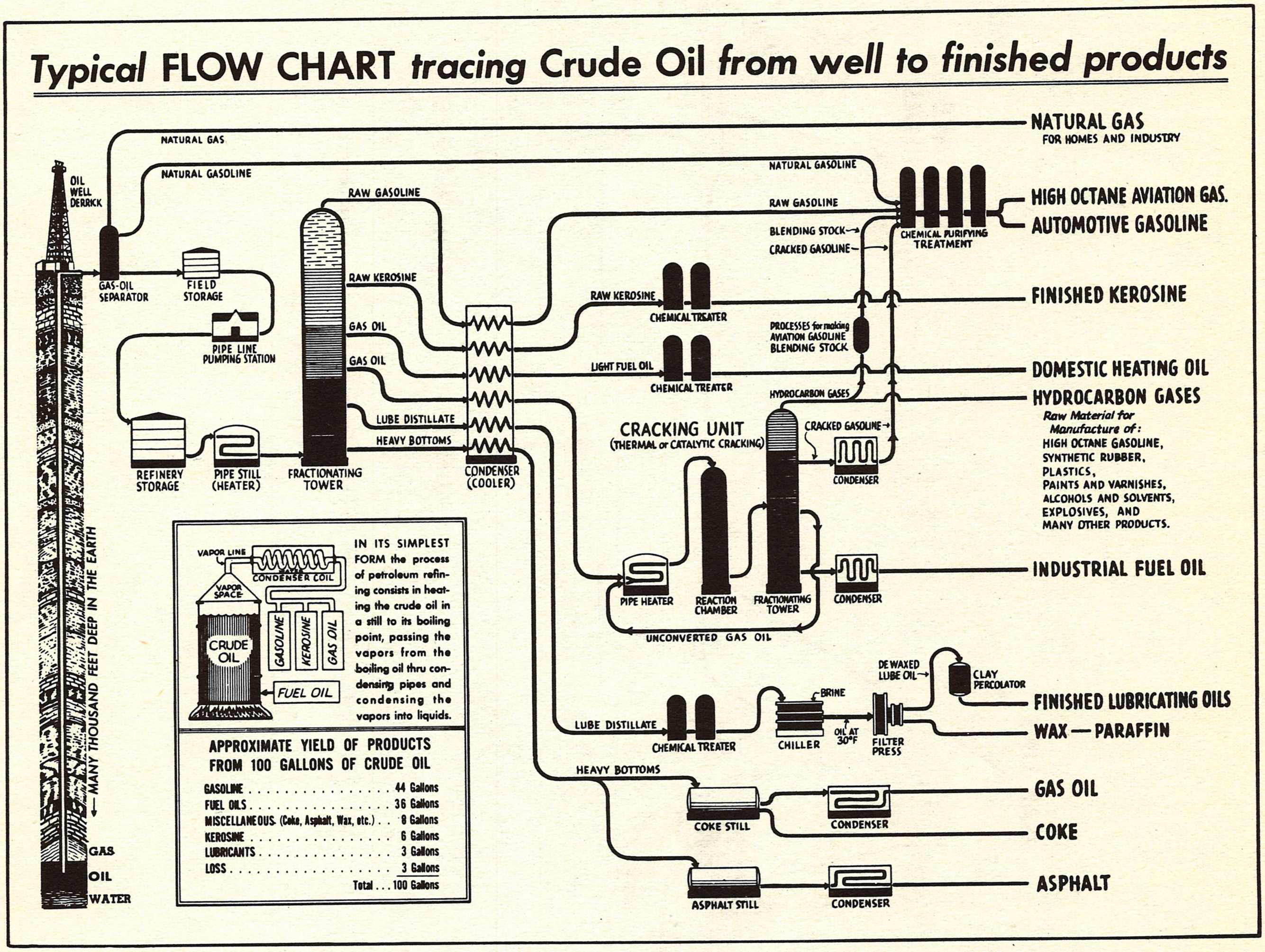
11-Sulfur content of a fuel should be:

a. High as possible
b. Low as possible
c. Does not matter

12-Liquid petroleum gas is a mixture of:
a. Benzol and heptane
b. Butane and propane
c. Butane and heptane
d. Heptane and cetane

13-The power of any fuel is determined by its:
a. Molecular weight
b. Heta value
c. The amount of carbon it contains

14-Immediately after ignition, combustion chamber temperatures may reach a value of:
a. 1500 deg.
b. 2500 deg.
c. 5500 deg.
d. 7500 deg.

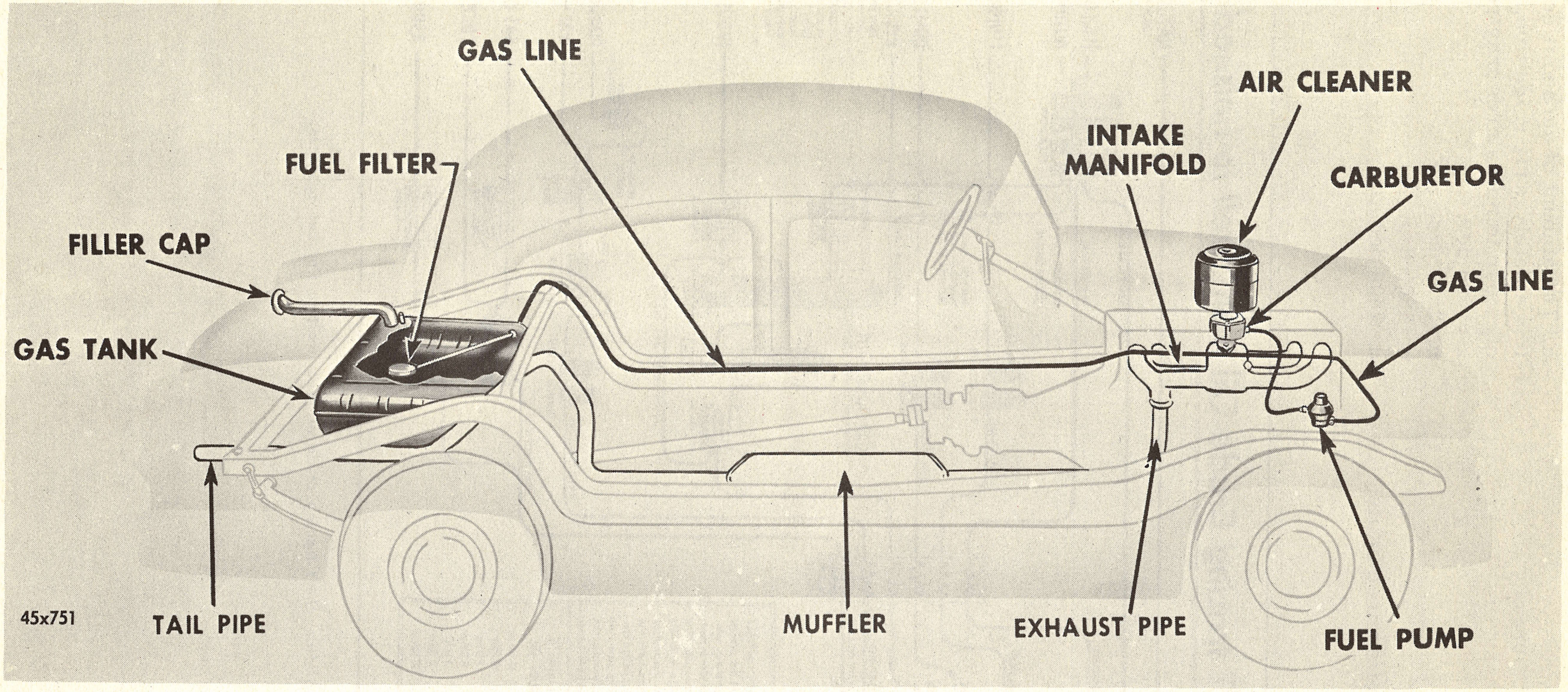

Typical FLOW CHART tracing Crude Oil from well to finished products
OIL WELL DERRKK
NATURAL GAS
NATURAL GASOLINE
GAS-OIL SEPARATOR
FIELD STORAGE
PIPE LINE PUMPING STATION
REFINERY STORAGE
PIPE STILL (HEATER)
FRACTIONATING TOWER
RAW GASOLINE
RAW KEROSINE
GAS OIL
GAS OIL
LUBE DISTILLATE
HEAVY BOTTOMS
CONDENSER (COOLER)
RAW KEROSINE
CHEMICAL TREATER
LIGHT FUEL OIL
CHEMICAL TREATER
NATURAL GASOLINE
RAW GASOLINE
BLENDING STOCK
CRACKED GASOLINE
CHEMICAL PURIFYING TREATMENT
PROCESSES for making AVIATION GASOLINE BLENDING STOCK
HYDROCARBON GASES
CRACKING UNIT (THERMAL or CATALYTIC CRACKING)
CRACKED GASOLINE
CONDENSER
PIPE HEATER
REACTION CHAMBER
FRACTIONATING TOWER
CONDENSER
UNCONVERTED GAS OIL
NATURAL GAS FOR HOMES AND INDUSTRY
HIGH OCTANE AVIATION GAS.
AUTOMOTIVE GASOLINE
FINISHED KEROSINE
DOMESTIC HEATING OIL
HYDROCARBON GASES
Raw Material for Manufacture of: HIGH OCTANE GASOLINE, SYNTHETIC RUBBER, PLASTICS, PAINTS AND VARNISHES, ALCOHOLS AND SOLVENTS, EXPLOSIVES, AND MANY OTHER PRODUCTS.
INDUSTRIAL FUEL OIL
DE WAXED LUBE OIL
CLAY PERCOLATOR
BRINE
LUBE DISTILLATE
CHEMICAL TREATER
CHILLER
OIL AT 30°F
FILTER PRESS
FINISHED LUBRICATING OILS
WAX — PARAFFIN
HEAVY BOTTOMS
COKE STILL
CONDENSER
GAS OIL
COKE
ASPHALT STILL
CONDENSER
ASPHALT
MANY THOUSAND FEET DEEP IN THE EARTH
GAS
OIL
WATER
VAPOR LINE
WATER
CONDENSER COIL
VAPOR SPACE
CRUDE OIL
GASOLINE
KEROSINE
GAS OIL
FUEL OIL

IN ITS SIMPLEST FORM the process of petroleum refining consists in heating the crude oil in a still to its boiling point, passing the vapors from the boiling oil thru condensing pipes and condensing the vapors into liquids.

APPROXIMATE YIELD OF PRODUCTS FROM 100 GALLONS OF CRUDE OIL

GASOLINE	44 Gallons
FUEL OILS	36 Gallons
MISCELLANEOUS (Coke, Asphalt, Wax, etc.)	8 Gallons
KEROSINE	6 Gallons
LUBRICANTS	3 Gallons
LOSS	3 Gallons
Total	100 Gallons

Typical flow chart tracing crude oil from well to finished products.


GAS LINE
AIR CLEANER
INTAKE MANIFOLD
CARBURETOR
FUEL FILTER
FILLER CAP
GAS LINE
GAS TANK
45x751
TAIL PIPE
MUFFLER
EXHAUST PIPE
FUEL PUMP

21-1. *Illustrating the parts of the fuel and exhaust systems on a passenger car.*

PRINCIPLES OF CARBURETION

The purpose of the complete fuel supply system is to provide a combustible mixture of fuel and air to the engine cylinders. The ratio of fuel to air must always be in the correct proportion regardless of the speed and load of the engine.

The complete fuel supply system consists of: fuel supply tank, fuel pump, carburetor, and manifold, Fig. 21-1. In addition, there are the fuel lines connecting the various units together, the fuel gauge for indicating the amount of fuel in the tank, the fuel filter, and the air cleaner.

EVAPORATION

The purpose of the carburetor is to prepare and supply a mixture of fuel vapor and air, in proper proportion for efficient combustion to the engine cylinders.

Because of the varying conditions such as temperature, engine speed and load on the engine, perfect carburetion is very difficult to attain.

First of all, when an internal combustion engine is started it is cold, and a fuel mixture containing a larger proportion of fuel is required. When the engine reaches operating temperatures, better vaporization of the fuel is attained, and as a result the initial mixture of fuel and air is too "rich." Such a mixture, which contains more fuel than is normally required, is not efficient, and the engine will not operate satisfactorily, particularly at idling speed.

Another difficulty that must be overcome by a carburetor is that when the engine is idling or operating at low speed, a richer mixture is required than when operating at medium speed and power. When maximum power is required, the amount of fuel in relation to air is again increased. Similarly, during periods of acceleration, a richer mixture is needed.

A difficulty encountered in designing carburetors results from the fact that the rate of air flow through the carburetor changes in a ratio of more than 100 to 1. This is a direct result of the changes of engine speed. At low speed, the flow of air through the carburetor is at a minimum, while at maximum engine speed, it will be 100 or more times as great.

Variations in types and characteristics of fuels also are complications to be overcome in efficient operation. Gasoline is a blend of various parts or fractions of crude petroleum. As a result, some of the fractions contained in present-day commercial gasoline will boil or vaporize at 100 deg. F., others at temperatures ranging up to 400 deg. F. Depending on the temperature of various parts of the intake manifold, some cylinders may receive a mixture with some portions of the fuel completely vaporized while other portions of the fuel may be in liquid form. In addition, some cylinders will receive fuel having greater antiknock qualities than others. Obviously when the engine and manifold are cold, the problem is still more difficult.

AIR-FUEL RATIO

For normal operating conditions, the best economy is obtained by a mixture of 1 part by weight of gasoline to between 16 to 17 parts of air. For quick acceleration and maximum power, a somewhat richer mixture is needed--one having about 1 part of gasoline to 12 to 13 parts of air. Also for idling, a somewhat richer mixture is required than for normal operation. Similarly, when starting a cold engine an extremely rich mixture is needed.

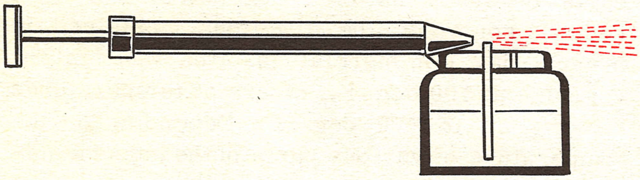
EVAPORATION

All substances, whether solid, liquid or gas, are made of molecules. In solids such as steel and copper the particles are held very closely together so that they seem to have no motion. In liquids, the molecules are not held together so tightly, so they can move with respect to each other. As a result, liquids can flow. In gases, such as air, there is still less tendency for the molecules to hold together, and they can therefore move quite freely.

When molecules of a liquid move from the liquid into the air, the liquid is said to evaporate. As this continues, the liquid disappears from its container and forms vapor in the air.

Rapidity of evaporation varies with a number of factors. These factors include temperature, the pressure above the liquid, the amount of liquid that has already evaporated into the air and the volatility. The term volatility refers to the ease with which a liquid vaporizes. For example, alcohol and benzine evaporate more easily than water. A highly volatile liquid evaporates rapidly, and a liquid of low volatility evaporates slowly.

At higher temperatures, molecules move faster, and as a result the rate of vaporization is increased. Furthermore, when there is little pressure above the liquid, the molecules can escape from the liquid more easily. If the evaporation is taking place in a closed chamber, the evaporation of the liquid will soon stop as the closed space above the liquid will soon become filled with escaped molecules of the liquid. The space above the liquid is then said to be saturated.



21-2. Fuel, as it leaves the jet in a carburetor, is vaporized in the same way as spray from a conventional spray gun.

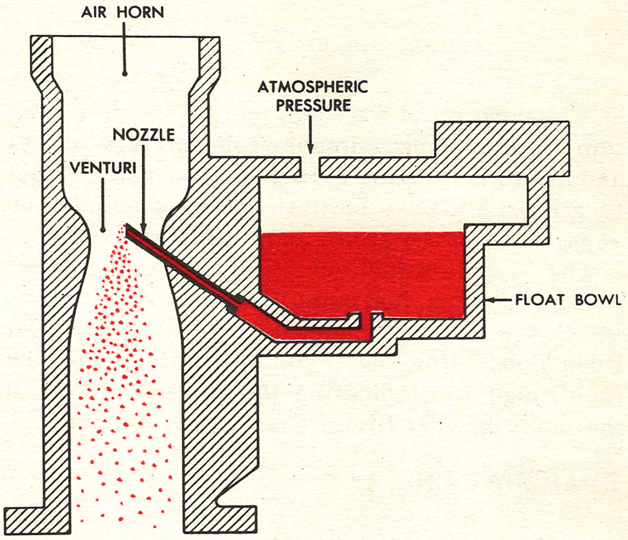
If a liquid is broken up into tiny particles or globules it will vaporize more easily. Breaking a liquid into tiny particles is known as vaporization. Spray guns such as are used for spraying insecticides or paint will vaporize a liquid. For example, if some gasoline is placed in an ordinary spray gun, Fig. 21-2, the fuel will be broken into a fine mist which will change into vapor almost instantly.

PRINCIPLES OF CARBURETOR OPERATION

Both air and gasoline are drawn through a carburetor and into an engine cylinder by suction created by the piston moving downward in the engine cylinder. In other words, as the piston moves down in the cylinder, a partial vacuum is created in the cylinder and combustion chamber. It is the difference between the pressure within the cylinder and the atmospheric pressure outside of the carburetor which causes air and fuel to flow into the cylinder from the carburetor.

The principle or method whereby the moving air draws fuel from the carburetor jet and fuel supply is important and of interest.

In order to increase the difference in pressure, i.e. increase the suction within the carburetor, a device known as a venturi is used. A venturi is an hour-glass shaped constriction placed in a carburetor, Fig. 21-3, so the incoming air must pass through it on its way to the intake manifold and the engine cylinders. A venturi is simply a specially designed section of a pipe line or tube, where the area of the tube is reduced. This reduction in area increases the speed of the air that is passing through the tube. Since the same volume of air or other fluid flows through all sections of the tube, it is obvious that if the area of the tube is decreased, the velocity of the air or fluid must increase as it passes through the restricted area.



21-3. Simplified carburetor consisting only of air horn, venturi, float bowl and nozzle or jet.

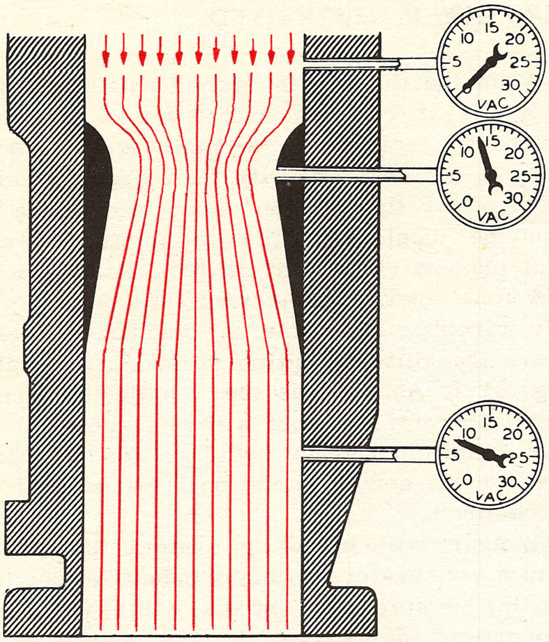
The venturi not only increases the velocity of the flow of air which passes through it, but it also produces a vacuum at its point of maximum restriction, Fig. 21-4. The outlet of a fuel jet is placed at that point, with the result the fuel is drawn from the jet and mixes with the passing air.

This mixing of the fuel with air is known as vaporization, and closely resembles the action of the familiar spray gun used for spraying insecticides, Fig. 21-2.

It must be remembered that it is the difference between the pressure at the open carburetor jet at the venturi, and the pressure on the surface of the fuel in the float bowl, Fig. 21-3 that causes the flow of fuel.

CARBURETOR CIRCUITS

A carburetor to supply a fuel mixture suitable for all the different operating conditions of low to high speeds, and light loads to full loads, must be provided with additional circuits and controls. These circuits include: the float system, the idle system, main metering system, accelerating system and high speed system. Under the heading of controls, there is included: the throttle, anti-percolator, fast idle, unloader, anti-icing, hot idle compensator, and anti-stall dashpot.



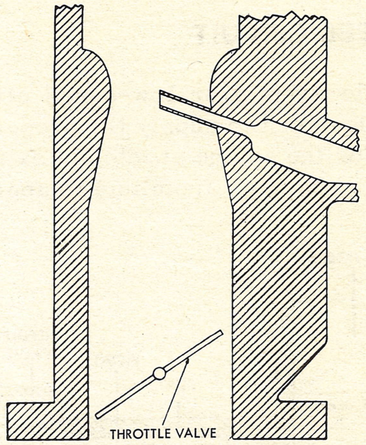
21-4. Note how vacuum varies through different sections of the carburetor.

THROTTLE

One of the important controls on a carburetor, is a device for varying the amount of air-fuel mixture that enters the intake manifold. This is necessary so the speed of the vehicle can be changed. The throttle, Fig. 21-5, is simply a round disk mounted on a shaft so that it can be tilted at various angles in the carburetor throttle valve body. It is connected by means of suitable linkage to the accelerator pedal in the driving compartment of the vehicle. Depressing the pedal opens the throttle valve, permitting an increased amount of air-fuel mixture to reach the manifold.

FLOAT CIRCUIT

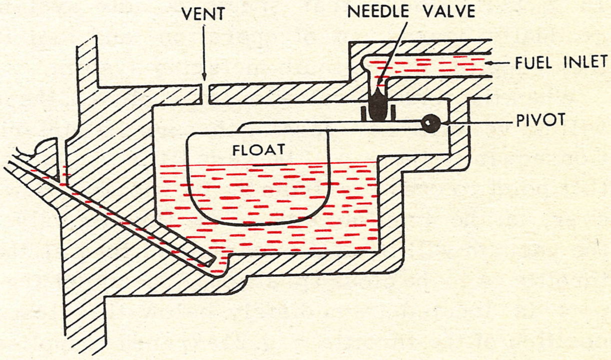
In order to keep the operating characteristics of the carburetor and its atomization of fuel as nearly constant as possible, it is essential that the level of the fuel in the jet is always maintained at the same level. This is accomplished by means of a float system, Fig. 21-6, which automatically permits fuel to flow into the float bowl when the fuel level drops below a predetermined value, and shuts off the supply of fuel when the level exceeds the specified height.



21-5. Illustrating the position of the throttle valve or plate.

Up-and-down movement of the float on the fuel, controls the fuel supply by means of a needle valve and seat.

The float level must be set with a high degree of accuracy, for if the fuel level is too low, insufficient fuel will be supplied to the jets, and engine performance will be sacrificed. On the other hand, if the fuel level is too high, excessive fuel will reach the jets. In fact, fuel will continue to flow from the jet, even when the engine is not operating. Not only will economy de-

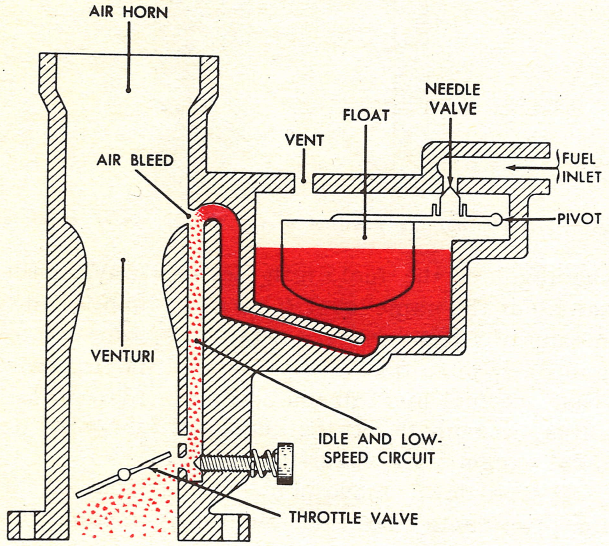


21-6. Typical carburetor float system.

crease but excessive carbon formations will form in the combustion chamber of the engine. In actual operation, the float and needle valve maintain a position that permits the fuel coming in to just balance the fuel that is flowing to the jets.

LOW-SPEED CIRCUIT

The idle system or low-speed circuit, Fig. 21-7, is designed to supply the proper amount of mixture for the engine at idle and extremely low speeds. It operates from idle to approximately 15 M.P.H. Above that speed the idle system gradually passes out of operation, and fuel is then supplied by the main metering system.



21-7. Details of carburetor idle system.

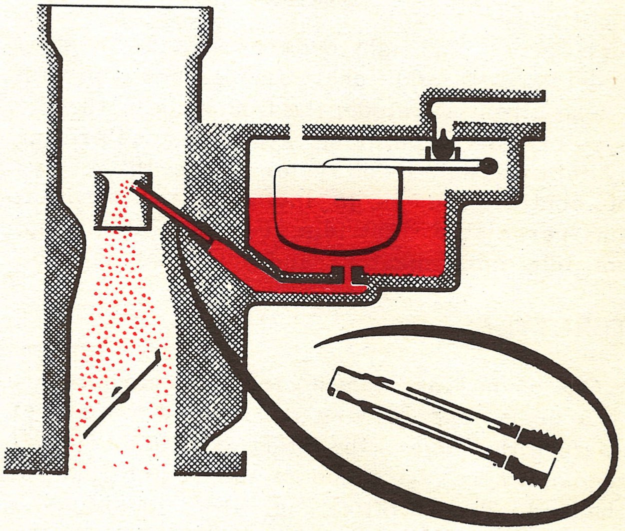
When the throttle valve is almost closed, there will be very little air passing through the venturi. Consequently there will be very little vacuum at that point to draw fuel from the fuel nozzle. However, on the manifold side of the throttle valve, the vacuum will be at a maximum as long as the throttle is in the closed position. A fuel discharge port is located immediately below the closed position of the throttle, Fig. 21-7, and is supplied by fuel from the float bowl. Atmospheric pressure in the float bowl will force fuel from the idle discharge hole as long as there is some degree of vacuum at the discharge hole. As the throttle moves toward the wide open position, the vacuum at the idle discharge hole continues to decrease until there is no flow of fuel from that port. An adjustable needle valve is provided so that adjustment can be made to govern the amount of fuel discharged from the idle port.

Immediately above the venturi is another port, Fig. 21-7, which is designed to permit air to bleed into the idle circuit as long as the idle circuit is operating. This air mixes with the fuel, and aids in its atomization before it leaves the idle discharge port.

AIR FLOW IS RESTRICTED

When the throttle is opened a little, the flow of air is still too restricted for the venturi to discharge fuel from the main jet or nozzle, Fig. 21-3. However, with the increased movement of air through the carburetor, more fuel must be supplied in order to maintain the correct proportions of air and fuel. To supply this additional fuel, another port is included in the idle circuit. This hole is positioned slightly above the closed position of the throttle valve, Fig. 21-7. As soon as the throttle is opened a small amount, the port will be uncovered. Intake manifold vacuum will act on this low-speed port, and the additional fuel needed will be obtained.

Another type of idling system is used on Zenith carburetors on many industrial engines. In this system, air mixes with the fuel in proportions determined by the postion of the idle adjusting needle valve. And the tube of the idling jet projects down into the well which is filled with fuel when the engine is at rest. As more air is admitted by means of the needle valve adjustment, less fuel will flow.



21-8. Main or high-speed system.

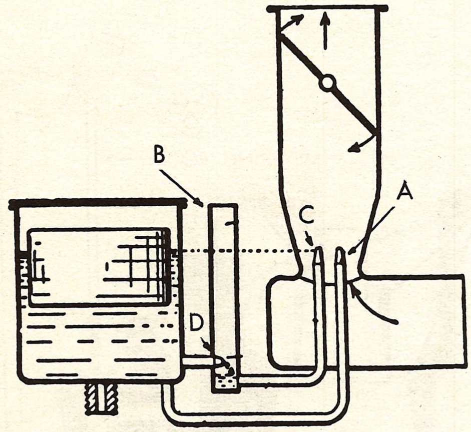
MAIN CIRCUIT

As the throttle is opened and the flow of fuel from the idle ports gradually decreases in volume, vacuum at the venturi gradually increases, so that fuel will start to flow from the main or high-speed system. The main system consists essentially of the main nozzle or jet which is centered in the venturi, Fig. 21-8, and supplies fuel from partly open to fully open throttle positions.

It must be remembered, that as the rate of flow of the air through the carburetor increases, the rate of flow of the fuel also increases, but at a much faster rate. This results from the fact that the density of the fuel does not change, while that of the air does. So in a simple carburetor, the mixture will be much too rich under wide open throttle conditions. In fact with a simple carburetor, the correct mixture of air and fuel would be provided at only one position of the throttle. Provision must therefore be made to supply the correct ratio of air to fuel for all positions of the throttle.

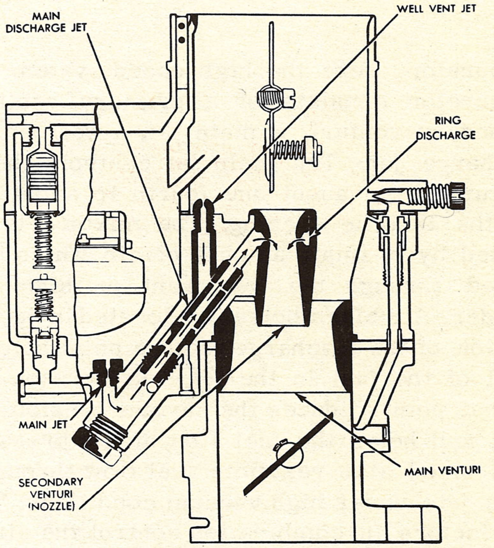
COMPENSATION OR DOUBLE NOZZLE PRINCIPLE

One method of controlling the mixture of fuel and air is to provide, in addition to the main nozzle, another nozzle with a constant rate of discharge. In combination, the two nozzles give substantially a constant mixture. In Fig. 21-9, the main nozzle is supplied with fuel directly from the float chamber. The compensating nozzle, which has a constant rate of discharge, is supplied from what is known as a standpipe, which receives its fuel from the float chamber. The upper end of the standpipe is open to the atmosphere. The supply of fuel in the standpipe is through a metered opening. As the fuel in the float chamber is at a constant level, the flow to the standpipe will be constant. In addition, the rate at which fuel can be drawn from the compensating nozzle will also be constant. At high engine speed, the compensating nozzle delivers less fuel than at low engine speed. In that way it compensates for the natural tendency of the main nozzle to deliver a mixture that is too rich at high speed.



21-9. The main nozzle (A) secures its fuel directly from the float chamber and the compensating nozzle (C) receives its fuel from the standpipe (B). The fuel supplied by nozzle (C) depends on the size of the metering orifice (D) which delivers fuel to the standpipe (B).

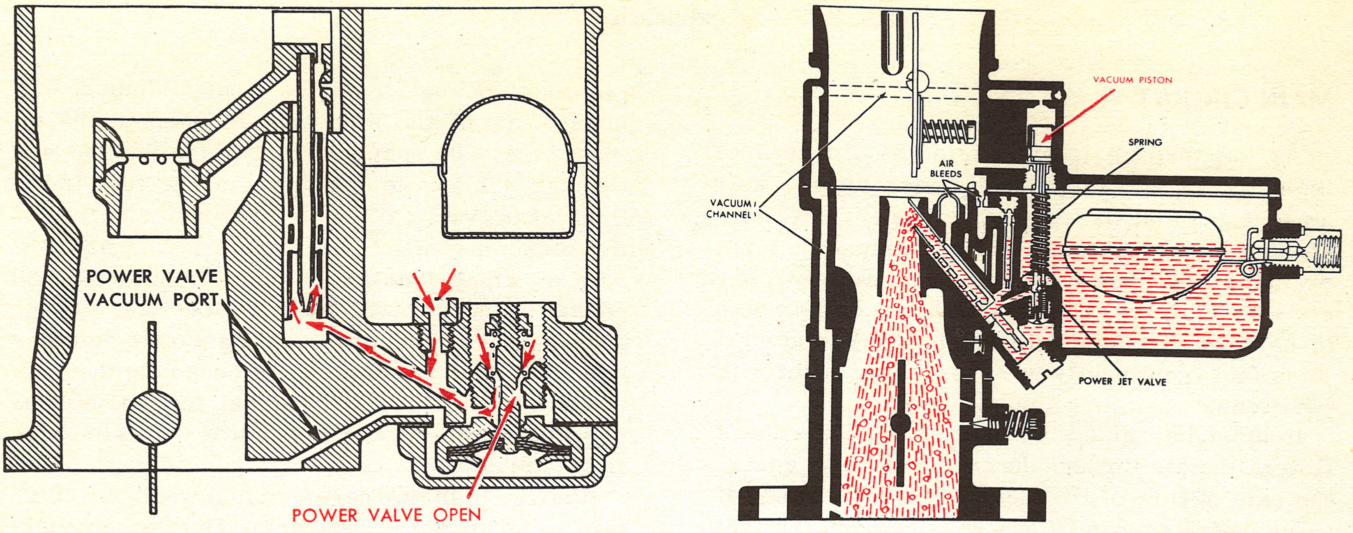
Also at high engine speed and when the compensating nozzle is delivering smaller amounts of fuel (due to reduced vacuum), the level of the fuel in the standpipe will rise until its level is equal to that in the float chamber. Then, as the suction on the compensating nozzle is such that fuel will be drawn from it, the fuel level in the standpipe will be lowered. If the throttle is maintained at the same opening for a sufficient length of time, all the fuel will be drawn from the standpipe, and the compensating nozzle will be supplied only from the compensating jet or submerged metering orifice.



21-10. Illustrating the air bleed principle as used on the Model 228 Zenith carburetor.

AIR BLEED PRINCIPLES

Another method of compensating for the increased richness of the mixture due to the effect of the plain nozzle with the increase in air velocity through the carburetor throat, is by means of air bleeds. The illustration, Fig. 21-10, shows the air bleed system as used on a Zenith



21-11. Left. The power valve, or economizer valve is designed to supply the additional fuel needed for maximum power at wide open throttle. 21-12. Right. Power jet valve controlled by vacuum piston supplies additional fuel for maximum power.

carburetor. Here the high speed system of the carburetor consists of a primary venturi, a secondary venturi, a main jet, a well jet and a discharge jet. The main jet controls the fuel mixture from about one fourth to about three fourths throttle opening. The mixture is controlled by a small amount of air which is admitted through the well vent or high speed bleeder. Air bleed holes are located in the upper section of the discharge jet at a point below the level of the fuel in the jet. Introduction of air at that point reduces the surface tension of the fuel, and helps the fuel flow at low pressures. This bleed also restricts fuel flow through the main jets under high vacuum conditions. These two factors in combination control the air-fuel ratio, and offset the tendency for increasing the richness of the mixture in a plain nozzle with increasing air velocity.

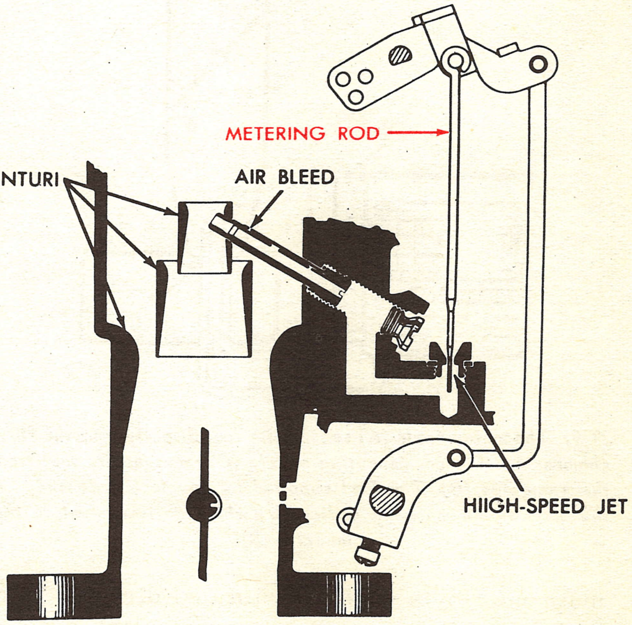
FULL POWER CIRCUIT

As pointed out, by means of the air bleed principle the air-fuel ratio is maintained at a constant rate. The system with its air bleed is then designed to provide economical operation for all speeds, from low speed up to but not including wide-open throttle. However, for maximum speed and power, additional fuel must be supplied. There are several ways that this additional fuel is provided for maximum power. These methods include the economizer valve or power jet, and the metering rod.

ECONOMIZER VALVE

The economizer valve or power valve, Fig. 21-11, as it is also called, depends upon manifold vacuum for its operation, and is connected to a point in the carburetor on the engine side of the throttle valve. The design is such that as full throttle operation is approached, the engine vacuum acting on the diaphragm or plunger of the power valve, will permit the required amount of fuel to pass through the main nozzle.

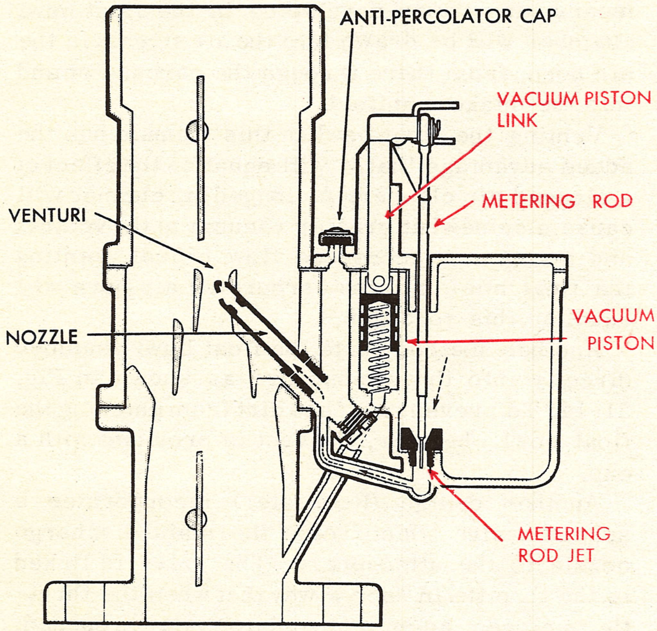
Another type of power jet is shown in Fig. 21-12. In this design, the power jet valve is controlled by a vacuum-actuated piston assembly, operating in accordance with throttle open-



21-13. The metering rod varies the amount of fuel flowing from a jet.

ing. With the throttle closed, a high manifold vacuum is present and the vacuum-controlled piston assembly is moved by atmospheric pressure in the float chamber to the top of its cylinder against the tension of a spring, closing the valve. When the throttle is opened to a point where additional fuel is required, the manifold vacuum has decreased sufficiently so that the spring on the piston assembly moves the piston down, opening the power jet to feed additional fuel into the high-speed circuit.

Mechanical means are also used for supplying the additional fuel needed for high speed operation. In such a design, the economizer or power jet is opened by the accelerator pump when the pump is at the bottom or end of its stroke.



21-14. Metering rod operated by vacuum-controlled piston.

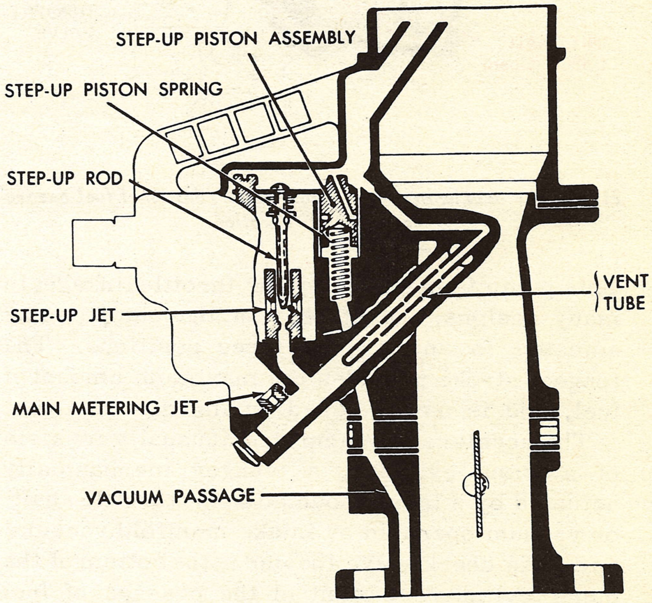
METERING ROD

Instead of using a power jet, some carburetors accomplish the same results by employing a metering rod which varies the size of the high speed jet openings. In this design, such as is used on some Carter carburetors, Fig. 21-13, fuel from the float bowl is metered to the high speed circuit through the calibrated orifice provided by the high speed jet, and the metering rod within it. From this point, the fuel is conducted to the nozzle extending into the venturi. As the throttle valve is opened, its linkage raises the metering rod in the jet. The rod has several steps or tapers on the lower end, and as it is raised in the jet, it makes the effective size of the fuel orifice greater, permitting more fuel to flow through the circuit. In this design, the metering rod position must be carefully synchronized with every throttle position, so that the proper air-fuel ratio is maintained throughout all engine speeds.

Metering rods are also operated by means of a vacuum controlled piston as shown in Fig. 21-14.

VACUUM STEP-UP

The vacuum step-up, Fig. 21-15, operates much like the power jet. It consists of a step-up piston which is fastened to a step-up rod. When high vacuum develops in the intake manifold, as it does during part throttle operation, atmospheric pressure holds the step-up piston down against its spring pressure so that in turn the step-up rod is held down in the step-up jet, closing the jet. With wide open throttle, there will be low vacuum in the intake manifold and the difference in pressure above and below the piston is small. Consequently, the piston is moved up by its spring pressure, and the rod is raised out of its jet, and in that way the additional fuel needed for maximum power is supplied.

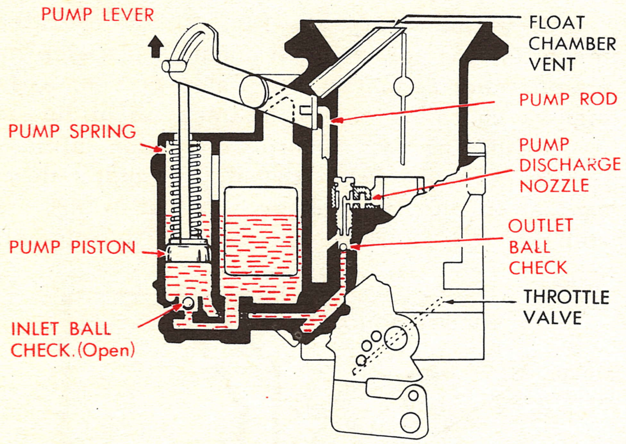


21-15. Details of the vacuum step-up circuit designed to supply the additional fuel needed for full power operation.

ACCELERATING PUMP

When a throttle is opened quickly to produce rapid acceleration of the engine, the carburetor fuel mixture tends to become too lean, and what is known as a "flat spot" results. This results from the fact that the fuel is of greater weight than air, and consequently when the accelerator is opened suddenly the flow of fuel will lag behind the flow of the air, resulting in a lean mixture.

To supply the additional fuel needed to overcome this condition, a small pump is incorporated in the design of the carburetor, Fig. 21-16.



21-16. The accelerator pump supplies the additional fuel needed for rapid acceleration.

This pump is operated by the throttle linkage. In many designs, the strokes of the pump can be adjusted to any one of three positions. The longest stroke provides the maximum amount of fuel, and is usually used during cold weather.

The accelerating pump circuit usually consists of a pump cylinder, a plunger mechanically actuated by a lever mounted on the throttle shaft, or vacuum operated by intake manifold vacuum; an intake check valve located in the bottom of the pump cylinder to control the passage of fuel from the bowl into the pump cylinder; a discharge or outlet check valve; and an accelerating jet to meter the amount of fuel used.

When the throttle is opened, the pump plunger moves downward in its cylinder. In the mechanically-operated design, the downward movement is obtained by direct linkage with the throttle. In the vacuum-actuated design, a sudden throttle opening will cause the manifold vacuum to drop, allowing the accelerating pump spring to force the pump plunger down in the cylinder. The downward travel of the plunger forces the fuel past the discharge check valve of the accelerating jet. Fuel is supplied to the pump cylinder through the intake check valve at the bottom. The intake check valve in the bottom of the cylinder permits a supply of fuel to reach the cylinder, but closes on the down stroke of the plunger, thereby preventing the fuel in the cylinder from being pushed backward into the float bowl.

ANTI-PERCOLATOR

During extremely hot weather, there is a tendency for the fuel to vaporize in the fuel line, the fuel pump or within the carburetor. This condition is known as vapor lock. To overcome this condition when it occurs in the carburetor special provisions are made. One method is to provide a passageway or vent tube between the top of the float bowl chamber, and the upper part of the air horn as shown in Fig. 21-17. By that means, any vapor developing in the float bowl chamber will be drawn into the air stream in the air horn, from there through the carburetor and into the intake manifold.

Venting the float bowl in this manner has the added advantage that it will equalize the effect of a clogged air cleaner. A clogged air cleaner will cause a somewhat greater vacuum at the venturi and consequent increased flow of fuel. Venting the float bowl into the carburetor air horn will equalize this condition.

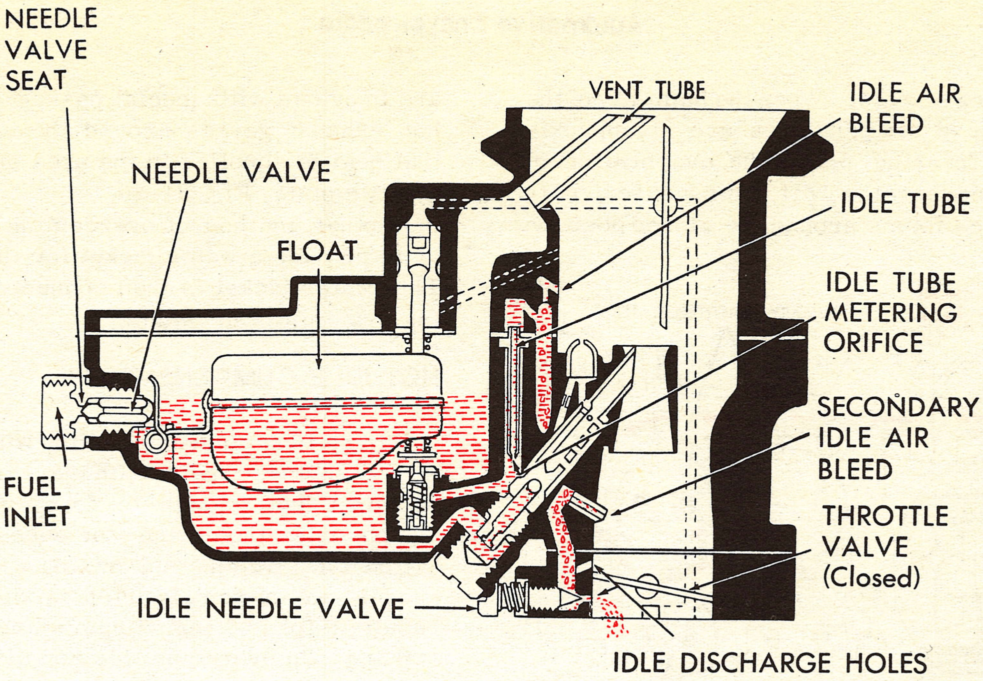
Another method vents the float bowl chamber directly into the atmosphere as shown in Fig. 21-14. To prevent dust and dirt from entering the float bowl chamber, the vent is provided with a cap.

Another design (Rochester) incorporates a special valve which vents the main discharge nozzle to the atmosphere. The valve is linked to the throttle in such a way that when the throttle is closed, an anti-percolator valve is opened. A similar method designed to accomplish the same thing provides a vent for the passages to the discharge nozzle without the use of a valve.

FAST IDLE

To prevent an engine from stalling until it reaches operating temperature, it is necessary that the engine be operated at a faster than normal speed. This is done by preventing the engine speed from dropping below a predetermined amount. To accomplish this, the choke shaft is linked to a cam on the outside of the carburetor, Fig. 21-18, so that as long as the choke is in a partially closed position the high spot on the cam comes under the fast idle speed adjusting screw. In that way the throttle will be held open a sufficient amount to prevent stalling.

After the engine reaches operating temperature, the operation of the choke will move the

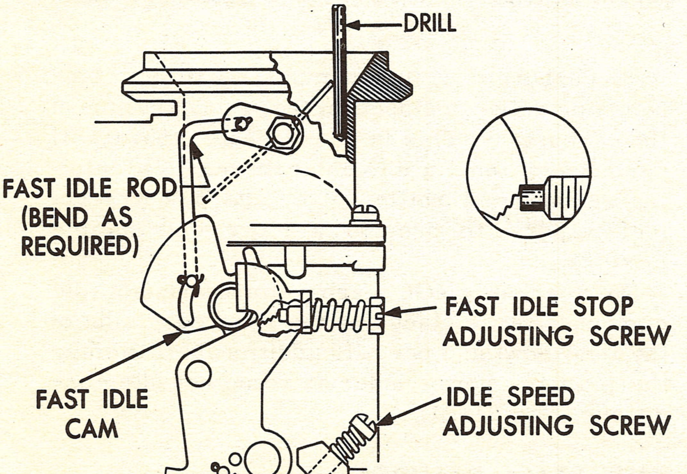

NEEDLE VALVE SEAT
NEEDLE VALVE
FLOAT
VENT TUBE
IDLE AIR BLEED
IDLE TUBE
IDLE TUBE METERING ORIFICE
SECONDARY IDLE AIR BLEED
THROTTLE VALVE (Closed)
FUEL INLET
IDLE NEEDLE VALVE
IDLE DISCHARGE HOLES

21-17. The vent tube from the float bowl to the air horn prevents vapor lock and also equalizes the effect of a clogged muffler. This illustration also shows a typical idling system.

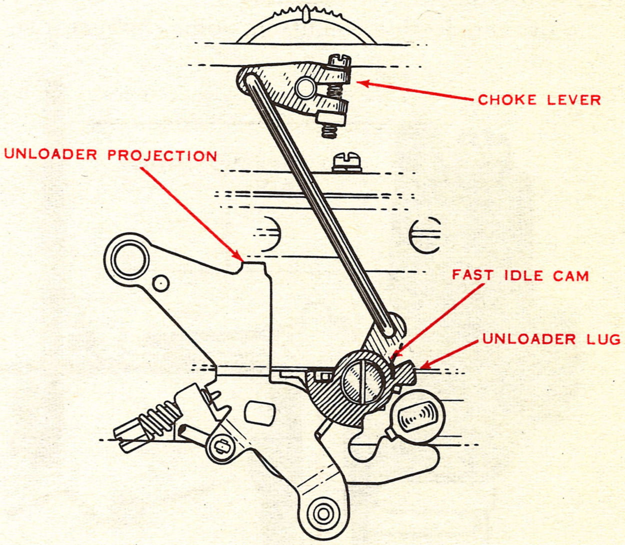
cam from under the fast idle speed adjusting screw so the engine will idle at a normal speed.

CARBURETOR UNLOADER

When an engine does not start immediately, prolonged cranking will result in a flooded condition. In other words, the mixture in the manifold and engine is so rich that it is no longer a vapor, and consequently will not explode. To overcome this condition, linkage is provided on the carburetor which when the accelerator is pushed to the floor, will hold the choke open, Fig. 21-19. Then as the engine is cranked again, air will enter the manifold and cylinders to clear the excessive gasoline from the system. This is accomplished by special linkage between the throttle and choke levers, Fig. 21-19.


DRILL
FAST IDLE ROD (BEND AS REQUIRED)
FAST IDLE STOP ADJUSTING SCREW
FAST IDLE CAM
IDLE SPEED ADJUSTING SCREW
THROTTLE LEVER TANG

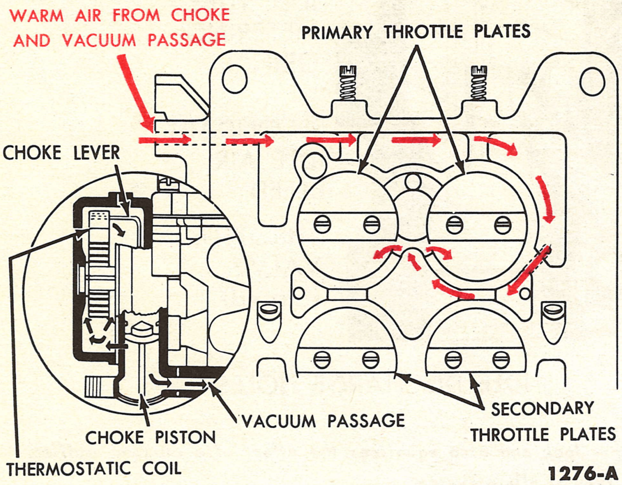
21-18. Showing the fast idle and choke linkage, together with fast idle adjustment and idle speed adjustment.


CHOKE LEVER
UNLOADER PROJECTION
FAST IDLE CAM
UNLOADER LUG

21-19. Showing the relation between the unloader lug or cam, the unloader projection, the choke lever and the fast idle cam.

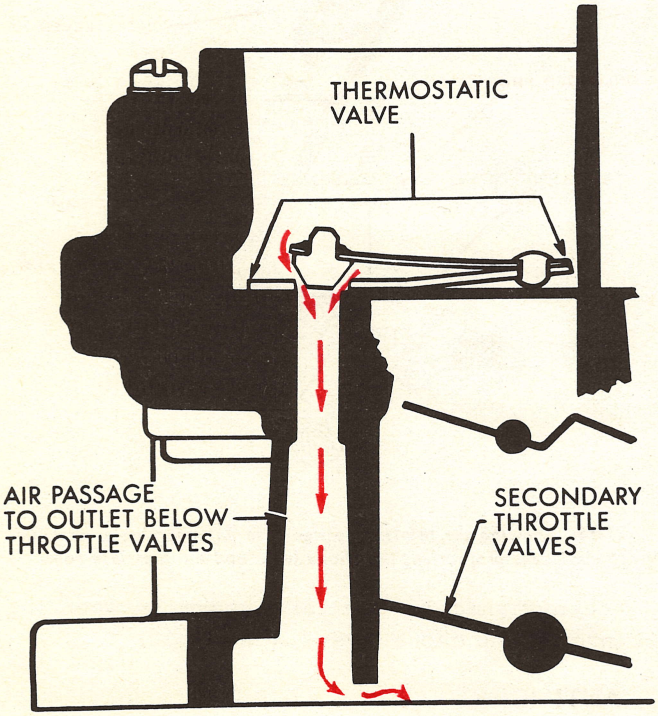
ANTI-ICING

When fuel is evaporated it absorbs heat, which it obtains from the surrounding air and metal parts of the carburetor. When the humidity of the air is high and temperatures are at approximately the freezing point, the evaporation of fuel in the carburetor will often cause ice to form. This ice forms around the closed position of the throttle, and the idle port will quickly become closed with ice. This in turn will cause the engine to stall at low speeds.


WARM AIR FROM CHOKE AND VACUUM PASSAGE
PRIMARY THROTTLE PLATES
CHOKE LEVER
CHOKE PISTON
VACUUM PASSAGE
SECONDARY THROTTLE PLATES
THERMOSTATIC COIL
1276-A

21-20. Showing path of warm air from the choke passing around the throttle valves to prevent the formation of ice.

To overcome this condition, some carburetors are provided with special passages which carry hot exhaust gasses around the carburetor, so that heat is supplied in the area surrounding the throttle plate, Fig. 21-20.

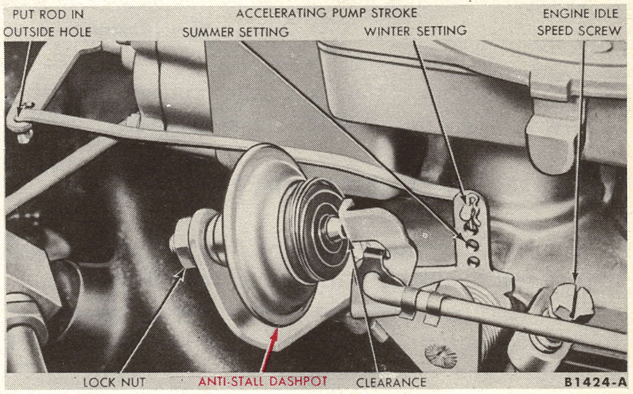

THERMOSTATIC VALVE
AIR PASSAGE TO OUTLET BELOW THROTTLE VALVES
SECONDARY THROTTLE VALVES

21-21. The hot idle compensator permits additional air to enter the primary bores of the carburetor under extreme hot idle conditions.

Another method of overcoming this difficulty is to provide a water jacket for the carburetor. This water jacket is then connected to the cooling system of the vehicle.

HOT IDLE COMPENSATOR

During long periods of idling with an extremely hot engine, the fuel in the carburetor bowl becomes hot enough to form vapors. These vapors enter the carburetor bores by way of the inside bowl vents, and mixing with the idle air causes an extremely rich mixture. This will result in loss of engine rpm's and eventually in stalling. To overcome this condition, on Carter AFB carburetors, for example, a hot idle compensator valve is placed in the secondary side of the carburetor. This is so calibrated that it will permit additional air to enter the manifold below the secondary throttle valve, and mix with the fuel vapors to provide a more combustible mixture.


PUT ROD IN OUTSIDE HOLE
ACCELERATING PUMP STROKE
SUMMER SETTING
WINTER SETTING
ENGINE IDLE SPEED SCREW
LOCK NUT
ANTI-STALL DASHPOT
CLEARANCE
B1424-A

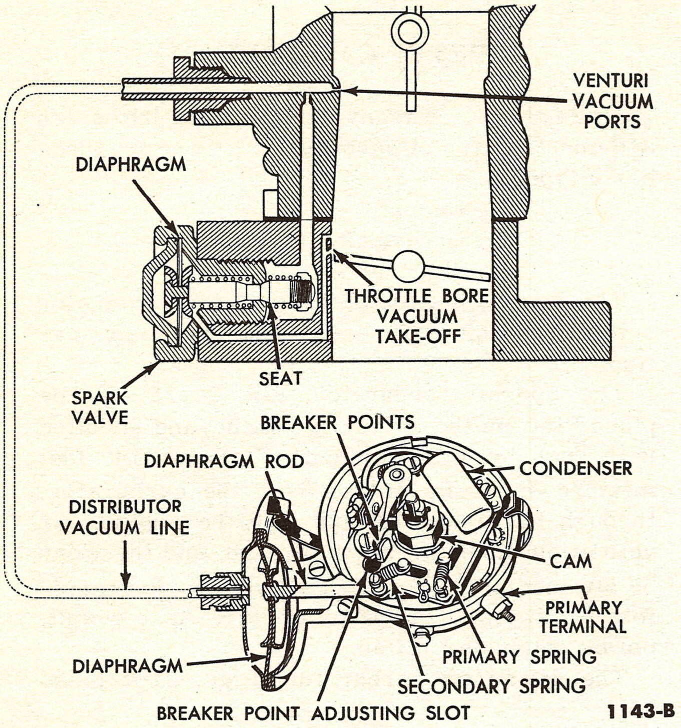
21-22. Showing anti-stall dashpot mounted on side of Ford carburetor. Some carburetors have the anti-stall dashpot built integral with the carburetor. Note provision for adjustment of accelerator pump.

On Rochester 4GC carburetors, the hot idle compensator is placed on the secondary side of the float bowl and permits additional air to enter the primary bores under extreme hot idle conditions, Fig. 21-21.

ANTI-STALL DASHPOT

Most cars with automatic transmissions have an anti-stall dashpot connected to the carburetor linkage, Fig. 21-22. The purpose of this dashpot is to prevent the throttle from closing too fast after the foot is removed from the accelerator pedal. Too rapid closing of the carburetor throttle will often cause the engine to stall. The installation of the dashpot prevents the throttle from being closed too quickly.

This would not occur with a conventional transmission, as the momentum of the vehicle would continue to drive the engine through the stall period.


VENTURI VACUUM PORTS
DIAPHRAGM
THROTTLE BORE VACUUM TAKE-OFF
SEAT
SPARK VALVE
BREAKER POINTS
DIAPHRAGM ROD
CONDENSER
DISTRIBUTOR VACUUM LINE
CAM
PRIMARY TERMINAL
PRIMARY SPRING
DIAPHRAGM
SECONDARY SPRING
BREAKER POINT ADJUSTING SLOT
1143-B

21-23. Method of using vacuum at the venturi and at the throttle to control spark advance.

In order to insure easy starting, it is essential that the carburetor throttle be open slightly. On modern cars, this is accomplished automatically by special linkage between the cranking motor and the carburetor throttle linkage. Whenever the starter is operated, the throttle will also be opened a slight amount.

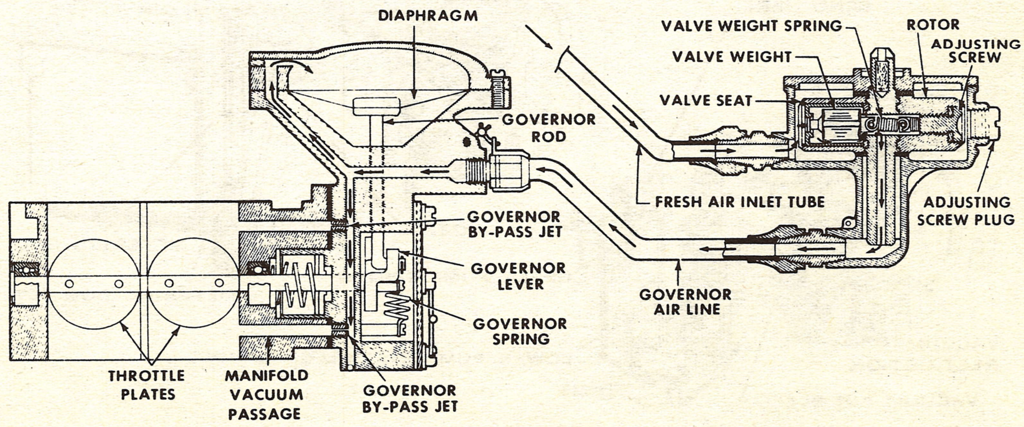
VACUUM ADVANCE

Vacuum from the carburetor is used to control the spark advance on the Ford Loadomatic distributor. In the latest design, vacuum is transmitted to the distributor diaphragm from three interconnected passages in the carburetor, Fig. 21-23. All manifold vacuum to the distributor passes through the spark control valve, Fig. 21-23. Under normal load conditions, the spark valve is held open against spring pressure by a combination of atmospheric pressure and manifold vacuum. When accelerating, manifold vacuum drops and spring pressure closes the spark valve, shutting off the vacuum and preventing excessive spark advance. Venturi vacuum prevents full retard. As manifold vacuum increases, the spark valve again allows a higher vacuum to advance the distributor.

GOVERNORS

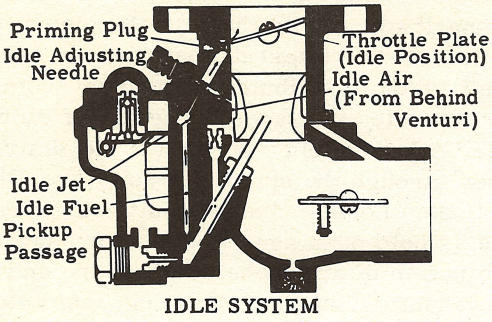
Governors are used principally on industrial engines and commercial vehicles so that economical and safe speeds are not exceeded. One type of unit, Fig. 21-24, is inserted between the carburetor and the intake manifold, and is actuated by the pressure differential acting against the governor diaphragm. This pressure differential is provided by the vacuum below the governor throttle plates, and the atmospheric pressure above the plates.

At low engine R.P.M., the governor control valve weight, of this Holley built unit, is held


DIAPHRAGM
VALVE WEIGHT SPRING
ROTOR
ADJUSTING SCREW
VALVE WEIGHT
VALVE SEAT
GOVERNOR ROD
FRESH AIR INLET TUBE
ADJUSTING SCREW PLUG
GOVERNOR BY-PASS JET
GOVERNOR LEVER
GOVERNOR AIR LINE
GOVERNOR SPRING
THROTTLE PLATES
MANIFOLD VACUUM PASSAGE
GOVERNOR BY-PASS JET

21-24. This Holley governor uses the vacuum below the governor throttle plates, and the atmosphere, to control the speed of the vehicle.

away from its seat by the tension of the valve weight spring. During this period the valve is wide open, allowing atmospheric air to flow to the governor so that no governing action occurs. As engine speed increases, the differential between atmospheric pressure and engine vacuum decreases, so the governor diaphragm is permitted to exert a pull on the governor lever which turns the throttle shaft and partly closes the throttle.


Priming Plug
Idle Adjusting Needle
Throttle Plate (Idle Position)
Idle Air (From Behind Venturi)
Idle Jet
Idle Fuel Pickup Passage
IDLE SYSTEM

21-25. Sectional view of updraft carburetor. Air enters at the right and passes upward through the venturi and past the throttle plate.

Another method of limiting the speed of an engine, is by means of a velocity type governor. In this design, the unit is inserted adjacent to the throttle, and the velocity of the gas going through the manifold acts on a spring-loaded floating obstruction in the form of a ball or disk attached to the throttle. As engine speed is increased, the velocity of the gas flowing through the manifold also increases and tends to carry the obstruction along with it. As this disk or ball is attached to the throttle plate of the carburetor, the result is to close the throttle against the tension of a spring. In that way, the speed of the engine is controlled.

TYPES OF CARBURETORS

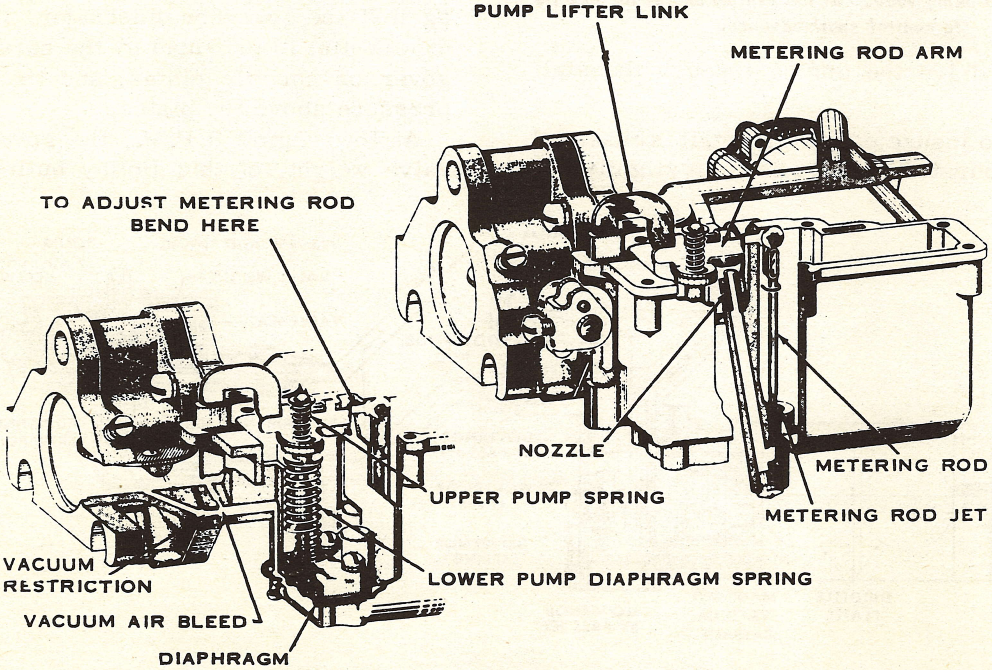
While there are many variations in the design and construction of carburetors, there are three basic types:

1. Updraft
2. Downdraft
3. Sidedraft

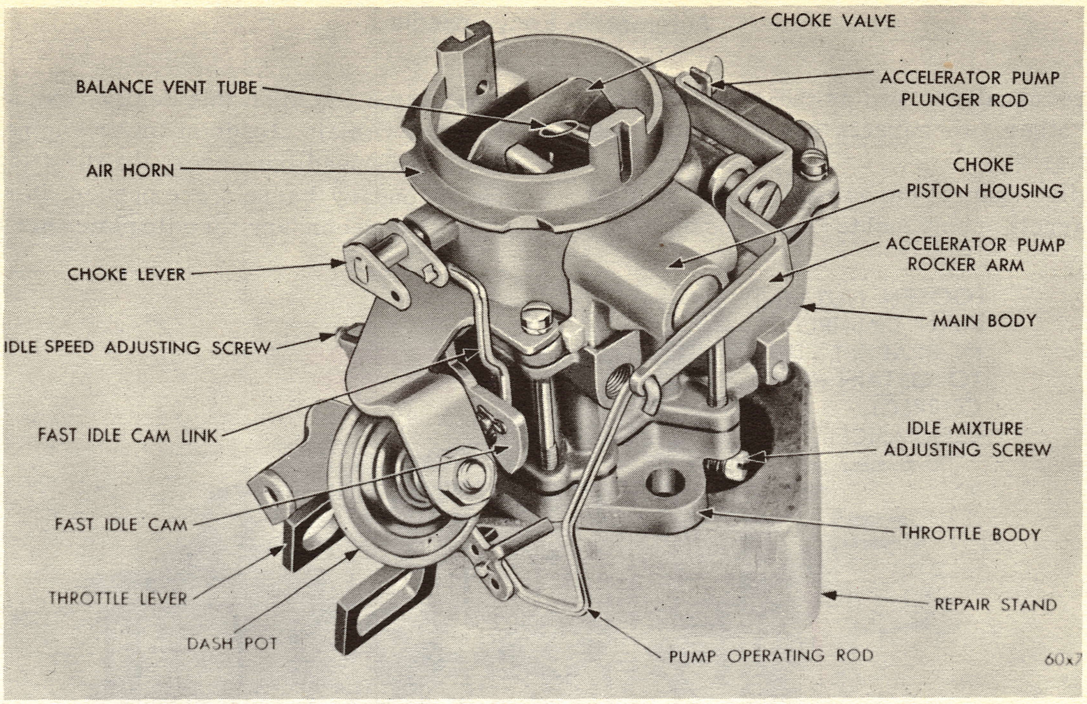
The direction of the air flow at the carburetor outlet to the manifold determines the classification.

The updraft carburetor, Fig. 21-25, can be placed low on the side of the engine, and supplied with fuel by gravity feed. However, the fuel mixture must be lifted from the carburetor, through the manifold, and into the engine. Air velocities must therefore be high, and these can be attained only by using carburetors and manifold passages of small diameter. As a result, power output is limited.

The downdraft carburetor, Figs. 21-12, and


PUMP LIFTER LINK
METERING ROD ARM
TO ADJUST METERING ROD BEND HERE
NOZZLE
METERING ROD
UPPER PUMP SPRING
METERING ROD JET
VACUUM RESTRICTION
LOWER PUMP DIAPHRAGM SPRING
VACUUM AIR BLEED
DIAPHRAGM

21-26. Side draft carburetor.


CHOKE VALVE
BALANCE VENT TUBE
ACCELERATOR PUMP PLUNGER ROD
AIR HORN
CHOKE PISTON HOUSING
ACCELERATOR PUMP ROCKER ARM
CHOKE LEVER
MAIN BODY
IDLE SPEED ADJUSTING SCREW
FAST IDLE CAM LINK
IDLE MIXTURE ADJUSTING SCREW
FAST IDLE CAM
THROTTLE BODY
THROTTLE LEVER
REPAIR STAND
DASH POT
PUMP OPERATING ROD
60x7

21-27. Single barrel downdraft carburetor. Note parts identification.

21-27, is used almost exclusively on American passenger car engines. In this design the fuel mixture will reach the engine, even though the air velocity is low. Carburetor throat and manifold can be made larger, which in turn makes high speeds and high specific output possible.

The side outlet carburetor (also known as the crossdraft) Fig. 21-26 is used on engines where there is little space over the engine and also where the vaporized mixture is heated by the water in the engine water jacket.

SINGLE BARREL CARBURETOR

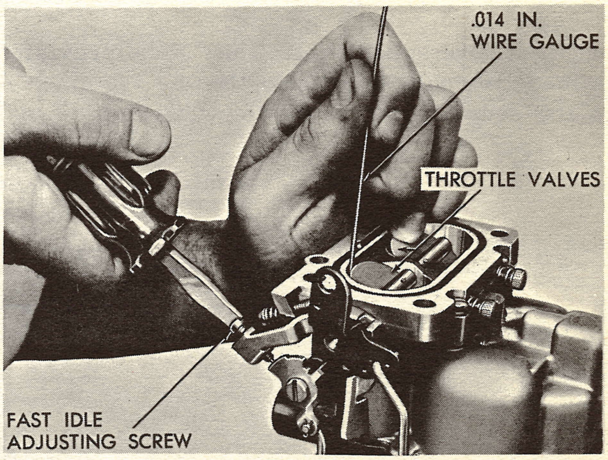
While there are three basic types of carburetors, they may also be classed in accordance with the number of throats or barrels. A single barrel carburetor, Fig. 21-27, has one outlet to the intake manifold. It is designed to take care of all the requirements of the engine for all operating conditions. Such carburetors are used extensively on engines of six cylinders or less.

DUAL CARBURETORS

Carburetors with two outlets to the intake manifold are known as two-barrel or two-throat carburetors, Fig. 21-28. Such a unit is basically two carburetors in one, and usually has two complete idling systems, two high-speed systems, two power systems, two accelerating systems, two throttles, two chokes, but only one float system.

With a dual carburetor, each barrel or mixing tube, supplies alternate cylinders in the firing order. In a conventional six cylinder engine, one barrel of the dual carburetor would supply cylinder numbers 1, 3 and 2, while the other barrel would supply cylinder numbers 5, 6 and 4.

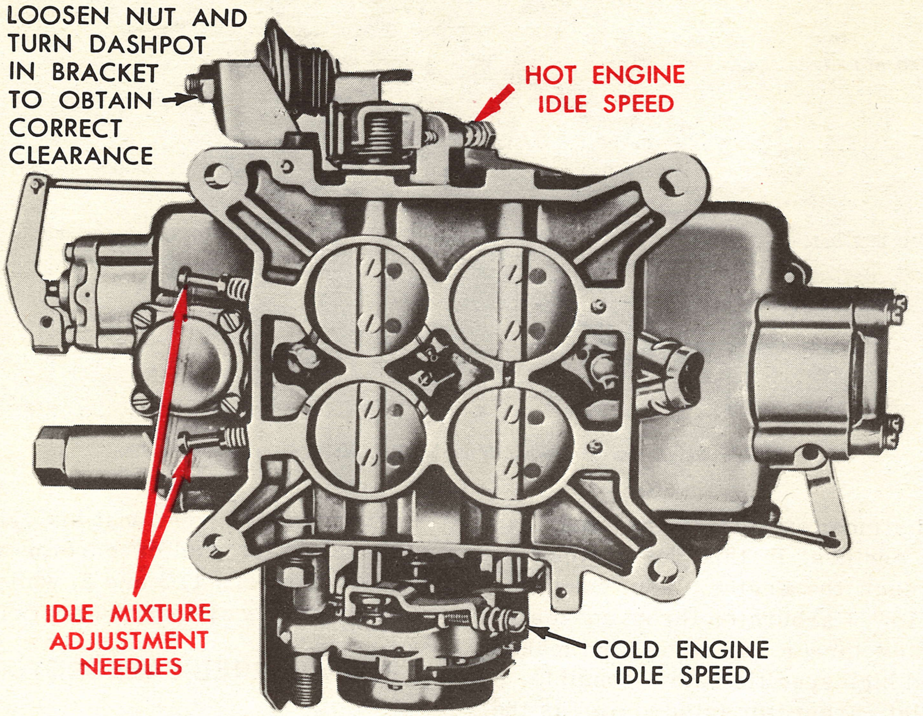
FOUR-BARREL CARBURETOR


.014 IN.
WIRE GAUGE
THROTTLE VALVES
FAST IDLE
ADJUSTING SCREW

21-28. Adjusting the position of the fast idle cam on this dual, or two-barrel carburetor.

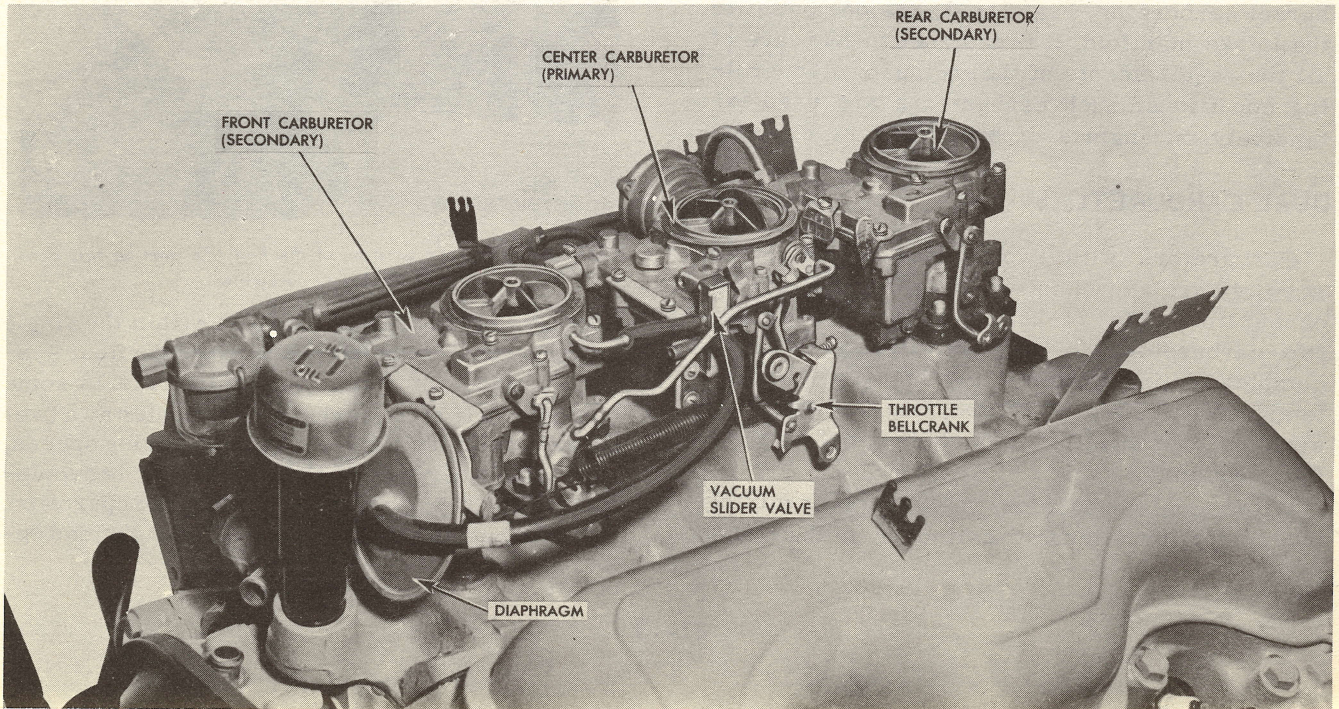
In the four-barrel carburetor, Fig. 21-29, generally used on V-8 engines, there are four openings to the intake manifold within the single unit. Some of the systems, such as the float system, may be common to all four barrels. In some designs, half of the carburetor operates as a two-barrel unit during light load and cruising speeds, while the other half of the carburetor is supplemental for top speed, and full-throttle operation. The two barrels supplying fuel for light load operation are usually known as the primary side, while the other two barrels are known as the secondary side.

When a four-barrel carburetor is designed so that two barrels supply fuel to the engine throughout the entire speed range, then some provision is made to route a portion of the idle system fuel to the secondary barrels for satisfactory fuel distribution. Also in this design, the secondary throttles remain closed at lower engine speeds. As engine speed increases, the throttle plates of the secondary barrels are opened. In some designs, the secondary throttle plates are operated mechanically through linkage. On other models, the secondary throttle plates are controlled automatically by a vacuum-operated diaphragm.


LOOSEN NUT AND TURN DASHPOT IN BRACKET TO OBTAIN CORRECT CLEARANCE
HOT ENGINE IDLE SPEED
IDLE MIXTURE ADJUSTMENT NEEDLES
COLD ENGINE IDLE SPEED

21-29. Bottom view of four-barrel carburetor, showing location of idle mixture adjustment, dashpot and hot engine idle speed adjustment.

21-30. Showing the installation of three dual carburetors on a Chevrolet V-8 engine.


REAR CARBURETOR (SECONDARY)
CENTER CARBURETOR (PRIMARY)
FRONT CARBURETOR (SECONDARY)
THROTTLE BELLCRANK
VACUUM SLIDER VALVE
DIAPHRAGM

In general, the secondary throttle plates will start to open when the primary plates are open 50 deg.

In a four-barrel carburetor, as used on V-8 engines, primary and secondary barrels form a pair to supply cylinders 1-7-4-6, while the other primary and secondary barrels will supply fuel to cylinders 3-5-2-8. However, this applies only to an engine having a firing order of 1-8-4-3-6-5-7-2. In general, manifolding for both two and four-barrel carburetors is designed so that one half of the carburetor will supply fuel to the end cylinders on one side of the engine, and the two center cylinders on the other side. The other half of the carburetor will then supply fuel to the remaining cylinders.

MULTIPLE CARBURETORS

Maximum performance requires perfect distribution of large quantities of the air-fuel mixture. One method of obtaining this is to use several carburetors. One installation on a V-8 engine uses three two-barrel carburetors.

In this installation (Chevrolet), the center carburetor is known as the primary, Fig. 21-30, and takes care of all engine requirements up to 60 deg. opening of the throttle. Above that, opening the secondary carburetors comes into operation, to supply the additional fuel required for maximum performance.

The primary carburetor is a complete unit and contains all the usual carburetor systems (Float, idle, choke, part throttle, power and accelerator pump). The front and rear carburetors do not include idle, part throttle or choke systems.

A combined mechanical and vacuum linkage is used to operate the throttles. The primary carburetor throttle is operated mechanically. When it is opened 60 deg., a vacuum slider valve is operated which causes vacuum to act on a diaphragm, which in turn operates the throttle valves on the secondary carburetors.

QUIZ - PRINCIPLES OF CARBURETION

1-What is the purpose of the fuel system in an internal combustion engine?

2-List the main parts of a fuel system.

3-The rate of flow through a carburetor is the same under all operating conditions. True _____ False_____.

4-When starting an internal combustion engine, the fuel mixture should be:
- a. Rich
- b. Lean
- c. Average

5-Which speed requires a richer mixture?
- a. Idling
- b. 30 mph

6-Will all cylinders of a multi-cylinder engine receive an air-fuel mixture having the same octane rating?

7-For normal operating conditions, what fuel-air ratio will give the best economy?
- a. 16 to 1
- b. 20 to 1
- c. 25 to 1

8-For quick acceleration, what is the best fuel-air ratio?
- a. 5 to 1
- b. 10 to 1
- c. 12 to 1
- d. 20 to 1

9-Are the molecules forming a gas held more tightly together than those of a metal?

10-Name two factors affecting the rapidity of evaporation.

11-What causes the air-fuel mixture to be drawn into the combustion chamber of an internal combustion engine?

12-The purpose of a venturi in a carburetor is to:
- a. Increase the speed of the air passing through the carburetor
- b. Maintain the correct air-fuel ratio
- c. Provide extra fuel for acceleration

13-There are five main circuits in a modern carburetor. Name four of them.

14-In a carburetor venturi, which point has the highest vacuum?
- a. Entrance to the venturi
- b. Narrowest point of the venturi
- c. Point one inch beyond the venturi

15-The idle system of a carburetor supplies fuel at what speeds?
- a. Idle speed only
- b. Speeds up to 40 mph
- c. Speeds up to 15 mph

16-How many fuel discharge ports does the conventional idle system have?
- a. One
- b. Two
- c. Three
- d. Four

17-When the idle system is no longer supplying fuel to the engine, which system then supplies fuel?
- a. Air bleed system
- b. Main system
- c. Vaporizing system

18-The purpose of an economizer valve is to supply more fuel, or less fuel?

19-The metering rod is designed to vary the size of which jets?
- a. Idle jets
- b. Accelerating jets
- c. High speed jets
- d. Float level jets

20-Under what conditions is ice most liable to form in a carburetor?
- a. 20 below zero and high humidity
- b. 32 deg. above zero and high humidity
- c. Zero deg. and low humidity

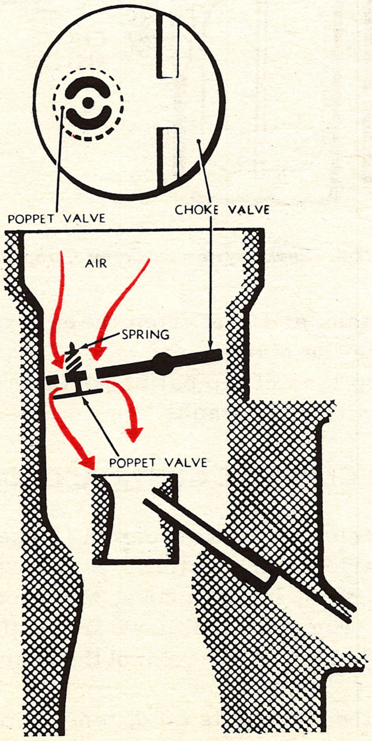
21-On what type of car are you most likely to find an anti-stall dashpot?
- a. Cars with automatic transmission
- b. Cars with conventional transmission
- c. Cars fitted with four-barrel carburetors

22-In addition to updraft and downdraft carburetors, what other basic type is there?

MANUAL, AUTOMATIC CHOKES

To start an internal combustion engine which is operated with gasoline, it is necessary to supply an extremely rich mixture. This mixture must be gradually leaned until the engine reaches operating temperature, after which operation will be maintained by the air-fuel ratios supplied by the carburetor.

The extremely rich mixture is secured by obstructing the air intake of the carburetor with a choke valve of the disk type, Fig. 22-1. With this choke valve closed very little air is admitted with the result that the suction, created by the piston on its down stroke, acts on the fuel nozzles and large quantities of fuel are drawn into the engine cylinder.



22-1. Details of choke valve or choke plate. Note that plate is mounted off-center on its shaft and is provided with a spring loaded poppet valve.

As soon as the engine is started, a somewhat leaner mixture is immediately required. Two methods are used to accomplish that condition. One method is to have the choke disk, or plate as it is also known, mounted slightly off-center on its shaft, Fig. 22-1. In that way, the atmospheric pressure will bear on a greater area on one side of the shaft than on the other, with the result that the disk will be forced open against spring pressure. Another method is to provide a small spring loaded poppet valve, which is built into the choke plate, Fig. 22-1. The engine suction, as soon as the engine starts, will pull this poppet valve open permitting air to pass through and dilute the mixture.

CHOKE CONTROLS

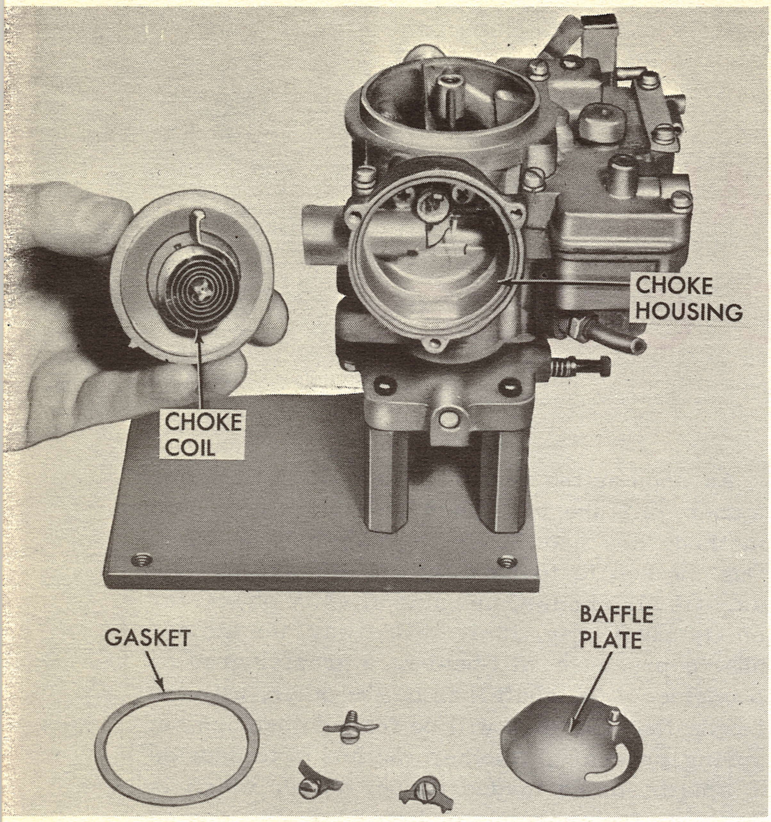
The opening and closing of the choke plate can be controlled manually or automatically. When it is manually controlled, a push-pull rod is provided which extends from the choke on the carburetor to the instrument panel. The driver can close the choke for starting the engine, and open it gradually as the engine reaches operating temperature.

The obvious difficulty with such an arrangement is that the driver is apt to forget to open the choke fully, with the result that the excessively rich mixture will cause carbon to form in the combustion chamber and on the spark plugs, with loss in power.

To overcome this difficulty, the automatic choke was developed. Some automatic chokes depend on exhaust manifold heat only for their operation, while others combine such heat with intake manifold vacuum and the velocity of air acting on the offset choke disk for their operation.

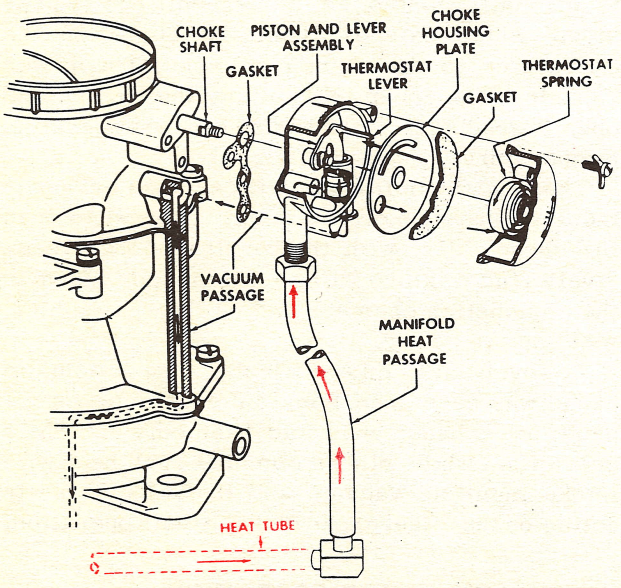
AUTOMATIC CHOKE OPERATION

The operation of an automatic choke depends primarily on the unwinding of a thermostatic


CHOKE HOUSING
CHOKE COIL
GASKET
BAFFLE PLATE

22-2. Parts of typical choke mounted on side of carburetor. Note particularly the choke coil.

coil spring, Fig. 22-2, as heat is supplied. As the spring unwinds, it causes the choke plate in the carburetor air horn to open, permitting more air to pass through the carburetor. Heat for the operation of the thermostat, in most cases, is obtained from the exhaust manifold. In one design, the thermostat is mounted in a well located in the exhaust manifold, Fig. 22-8. Movement of the thermostatic coil is then transmitted to the choke valve by means of linkage and levers.

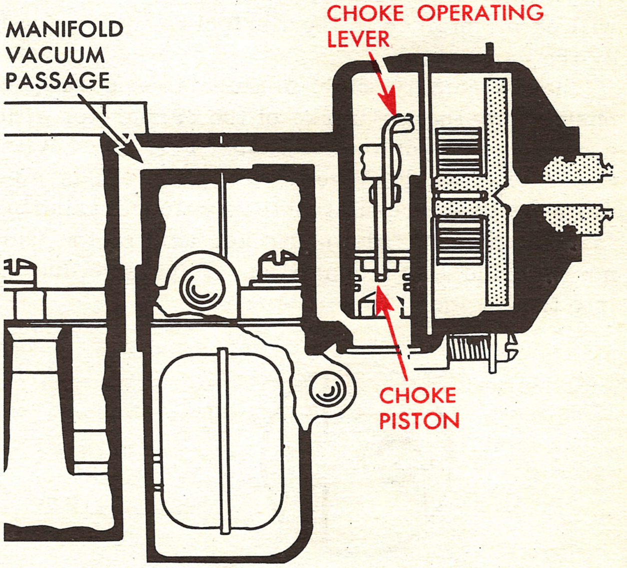

CHOKE SHAFT
PISTON AND LEVER ASSEMBLY
CHOKE HOUSING PLATE
GASKET
THERMOSTAT LEVER
THERMOSTAT SPRING
GASKET
VACUUM PASSAGE
MANIFOLD HEAT PASSAGE
HEAT TUBE

22-3. Exploded view of automatic choke mounted on side of carburetor. Note the heat tube which supplies heat from the exhaust manifold.

When the thermostat is mounted on the side of the carburetor, Fig. 22-3, it is necessary to conduct the heat from the exhaust manifold to the thermostat. This is accomplished by passing a tube through the exhaust manifold, so that as air is drawn through the tube it is heated by the exhaust gases passing around the tube. This tube then conducts the heated air to the thermostat.

To aid the circulation of this warm air around the thermostat, vacuum connection is made with the intake manifold, Fig. 22-4.

Another design of automatic choke uses electrical means and heat from the exhaust manifold to operate the choke.


MANIFOLD VACUUM PASSAGE
CHOKE OPERATING LEVER
CHOKE PISTON

22-4. Choke system on Carter Carburetor.

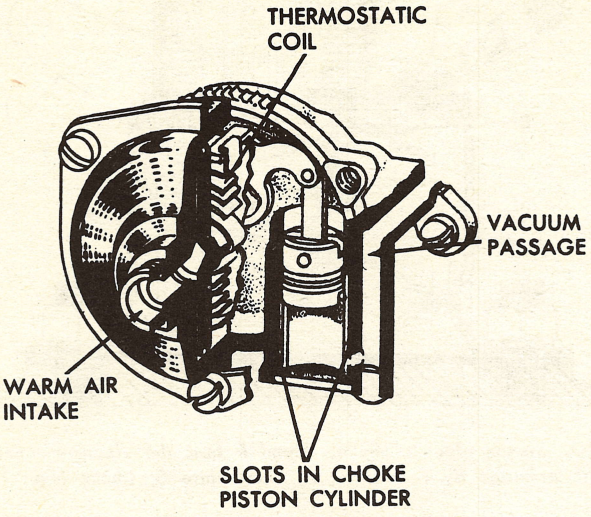
Descriptions of typical chokes are provided in the following paragraphs.

CARTER CLIMATIC CONTROL CHOKE

The Carter Climatic Control Choke as used on many Carter carburetors, is shown in Figs. 22-4 and 22-5. In this choke, air velocity, intake manifold vacuum and heat from the exhaust manifold, are used to control the operation of the choke.

When the engine is cold, tension of the thermostatic coil, Fig. 22-5, holds the choke plate closed. When the engine is started, air velocity against the choke plate causes the choke to open slightly against the tension of the thermostatic coil. Intake manifold vacuum applied to the choke piston, Fig. 22-5, pulls the choke piston down, opening the choke valve. The choke valve assumes a position where the tension of the thermostatic coil is balanced by the pull of the vacuum on the piston and air velocity on the offset choke plate.

When the engine starts, slots in the side of the choke piston Fig. 22-5, are uncovered allowing intake manifold vacuum to draw warm air from the hot air tube located in the exhaust manifold through the center of the choke housing, Fig. 22-4. The hot air passes around a delayer plate on which the choke thermostatic coil is mounted. The incoming air loses some of its heat to the delayer plate, keeping the choke on longer to improve warm-up performance. The flow of warm air in turn heats and expands the thermostatic coil, causing it to gradually lose some of its tension, until finally the choke valve assumes wide open position.



22-5. Details of Carter choke shown in Fig. 22-4.

When the engine is accelerated during the warm-up period the corresponding drop in manifold vacuum applied to the choke piston, allows the thermostatic coil to momentarily close the choke valve, providing the needed richer mixture.

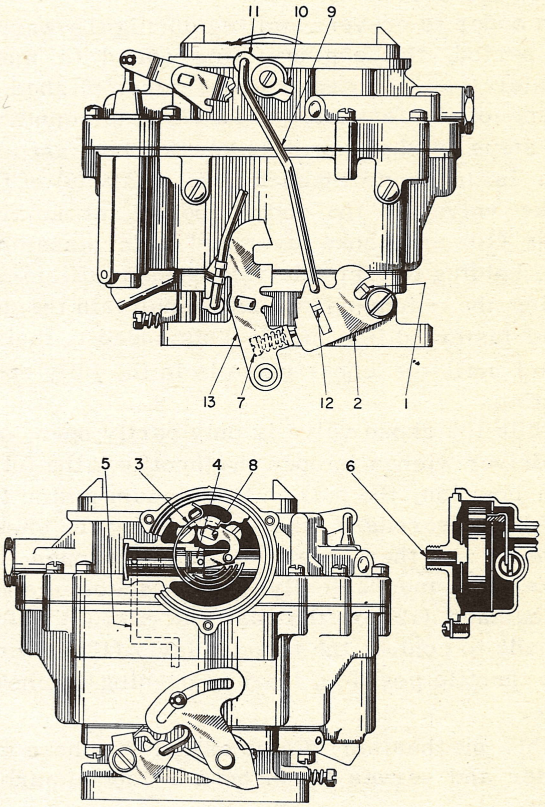
The fast idle linkage as used on this carburetor, is shown in Fig. 21-18.

Should the engine become flooded during the starting period, the choke valve can be opened manually by depressing the accelerator pedal to the floor. The unloader projection, Fig. 21-19, will then rotate the fast idle cam and in turn open the choke valve.

ROCHESTER AUTOMATIC CHOKE

The automatic choke system as used on the four-throat Rochester carburetor, Fig. 22-6, consists of a thermostatic coil (3) vacuum piston (4) offset choke valve and fast idle cam (2). Its operation is dependent on the combined effects of intake manifold vacuum, the offset choke valve, atmospheric and exhaust manifold heat.

When the engine is cold the tension of the coiled thermostatic springs keeps the choke valve in the closed position. Then, as the engine starts, the velocity of the air passing through the carburetor air intake acting against the offset choke valve tends to force it into the open position against the tension of the thermostatic spring. At the same time, intake manifold vacuum acts on the vacuum piston (4) through the passage (5) which also tends to open the choke valve. In other words, the choke valve assumes a position where the torque of the thermostatic coil is balanced by the vacuum pull on the choke piston and air velocity against the offset choke valve. This causes a regulated air flow into the carburetor providing a richer mixture during the engine warm-up period.



22-6. Details of automatic choke used on Rochester carburetors.

Also during the warm-up period, the vacuum piston (4) serves to modify the choking action to compensate for different engine loads. As any acceleration or increased load decreases the vacuum exerted on the choke piston, the thermostatic coil torque momentarily increases the closure of the choke valve, thereby providing the needed richer mixture for acceleration.

As the engine temperature increases, hot air from the exhaust manifold is drawn into the thermostatic coil housing through the connection (6). This warm air acting on the thermostatic coil (3) causes it to relax its tension. As a result the choke valve gradually assumes a fully open position.

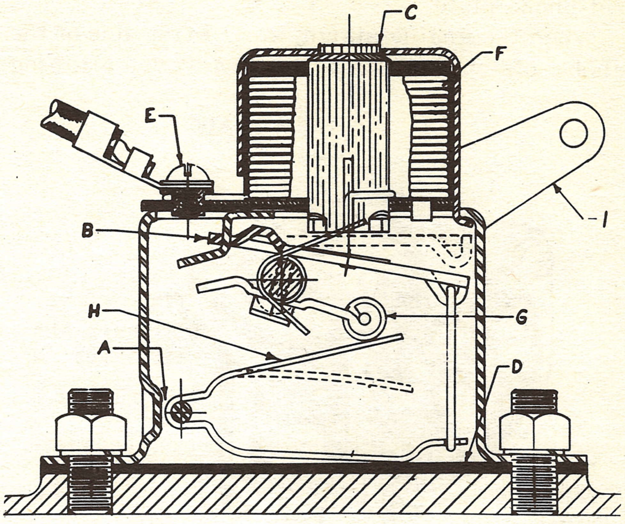
In order to prevent stalling during the warm-up period, the engine idling speed is made greater than normal. This is accomplished by means of the fast idle screw (7) which contacts the steps of the fast idle cam (2). The fast idle cam is in turn linked to the shaft (8) of the choke valve by the choke rod (9), choke trip lever (10) and choke lever and collar assembly (11), holding the throttle valves open sufficiently during the warm-up period to maintain the desired faster idling speed. This speed is maintained until the choke valve is in the fully open position.

While the choke valve is only partly open, and the driver wishes to open the throttle to the fully open position, the pull on the vacuum piston (4) would be decreased, thereby closing the choke valve. It is therefore necessary to open the choke valve mechanically. This is accomplished by the tang (12) on the fast idle cam (2) which is made to contact the throttle lever (13) at wide open throttle position, thereby opening the choke valve.

This mechanism is also called the choke unloader and serves to unchoke a flooded carburetor.

SISSON AUTOMATIC CHOKE

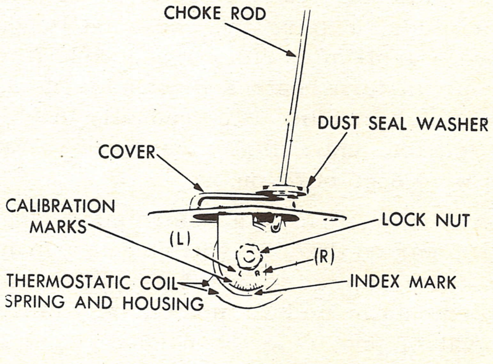
The Sisson automatic choke, Fig. 22-7, controls the position of the choke valve by means of an electro-magnet and a thermostat. The unit is mounted on the exhaust manifold and is connected to the choke valve by means of a rod and levers. The electrical circuit is controlled through operation of the starter switch. When the starter switch is operated, the choke circuit is closed so that current flows through the electro-magnet in the choke. This operates the choke lever, closing the choke valve. As soon as the engine is started, the starter switch is opened and the choke circuit is also opened. This demagnetizes the choke electro-magnet and the position of the choke valve is then controlled by the thermostat. Then, as the engine attains operating temperature, the choke valve is fully opened. Should the engine be started when it is hot, the tension of the thermostat will hold the choke open against the action of the electro-magnet.



22-7. Sisson electric choke. C and F form the electro-magnet with Armature B, Thermostat H, Shaft plate G, Choke lever I.

CROSS OVER TYPE CHOKE

This automatic choke is thermostatically operated. The thermostatic coil, Fig. 22-8, is mounted in a well in the exhaust cross over in the intake manifold on V-type engines. The operation of the choke valve is controlled by the thermostatic spring, the choke piston, Fig. 21-27, and by the offset position of the choke valve on its shaft.



22-8. Details of cross over type thermostatic choke control, which is mounted in a well in the exhaust cross over in the intake manifold.

As the thermostatic coil gains heat, it gradually unwinds and allows the choke plate to open. At the same time, the vacuum-operated choke piston, connected by a rod to the valve, keeps a constant pull on the valve against the tension of the spring. This continues as long as the engine is operating. Thus the choke valve opens gradually. In addition the offset position of the choke valve on its shaft also tends to open the valve as the result of the velocity of air passing.

QUIZ - MANUAL, AUTOMATIC CHOKES

1-Is a lean mixture or a rich mixture required to start a cold engine?

2-What two methods are used to control the operation of a choke?

3-Where is the heat used to operate an automatic choke usually obtained?

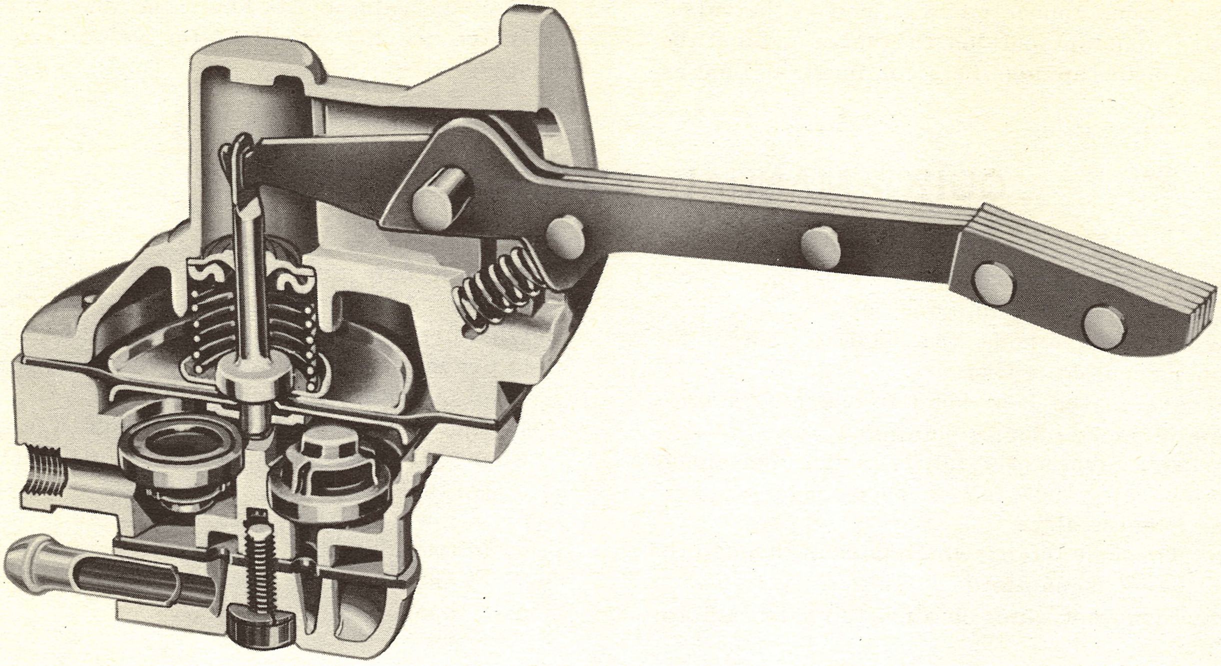
4-When thermostatic coil is mounted on side of carburetor, how is heat supplied?
  a. Electrically
  b. Through tubing which passes through the exhaust manifold
  c. From hot water obtained from the radiator

5-Explain how air velocity is used in some chokes to aid in the operation of the choke.

6-What provision is made in carburetor linkage to prevent stalling during the warm-up period of an internal combustion engine?

7-In the cross-over type automatic choke, where is the thermostatic coil located?
  a. On the side of the carburetor
  b. In a well in the exhaust manifold
  c. In the hot water jacket of the engine

8-What is the major disadvantage of the manually operated choke?



Sectional view, fuel pump from Ford V-8 engine, 221 cu. in.

ENGINE MANIFOLDS

INTAKE MANIFOLDS

The intake manifold connects the carburetor or carburetors to the intake ports of the engine. The exhaust manifold connects the exhaust ports of the engine to the exhaust pipe or pipes, which in turn lead to the muffler. Originally, because of the characteristics of the fuel being used, intake manifolds were of simple construction. However, in order to insure satisfactory distribution of present day fuels and keep the fuel vaporized, heat is supplied to the intake manifold. This is accomplished by surrounding a part of the intake manifold with a jacket which is supplied with heat from the exhaust manifold.

The difficulty in designing intake manifolds is to provide each cylinder with the same quality and quantity of fuel. As pointed out in the section on fuels, gasoline is a mixture of various hydrocarbons, some of which vaporize more easily than others. Equal distribution of the fuel to each cylinder could be more easily attained if the gasoline consisted solely of easily vaporized fuel. In order to keep the different components that form gasoline vaporized, heat is applied to aid in the vaporization. Heat tends to reduce the volumetric efficiency of the engine; that is, smaller amounts of the combustible mixture will reach the cylinder and in that way power will be reduced.

MANIFOLD HEAT

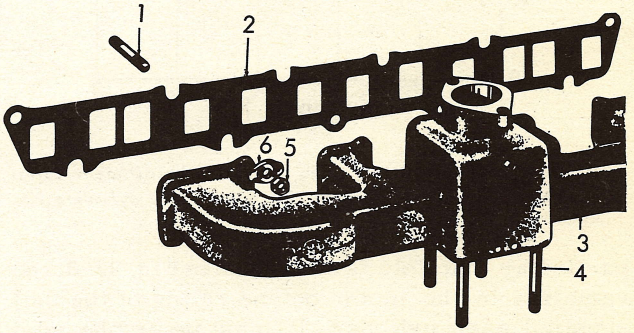
On in-line engines heat is applied to the intake manifold by surrounding a central section with a heat jacket, Fig. 23-1, through which hot exhaust gases are directed. Another design is to have a small section of the intake manifold in contact with the exhaust manifold.

On V-8 engines, where the intake manifold is situated between the two banks of cylinders, special passageways are included in the design of the manifold. These passageways conduct hot gases from the exhaust manifold close to the intake passageways, to provide the necessary heat.

In order to regulate the amount of heat reaching the intake manifold from the exhaust, a thermostatic valve is provided. These valves and their operation are described in detail on page 23-4.

UNEQUAL DISTRIBUTION

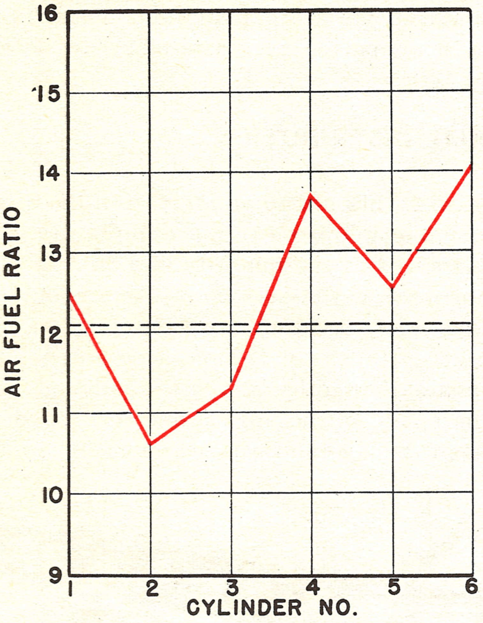
Even with this aid to vaporization the mixture in the intake manifold is not completely vaporized. As a result the quantity and quality of fuel reaching each cylinder varies. As a result some cylinders will develop more power than others and some cylinders will have a greater tendency to detonate than others. This condition varies with the speed of the engine and it is necessary to design and adjust the carburetor so as to provide an adequate mixture for what would otherwise be the weak cylinder. The other cylinders will then receive a mixture that is too rich.



23-1. Intake manifold with gasket. The square section at the center is the heat jacket supplied with hot exhaust gases from the exhaust manifold which is bolted directly to it by the studs (4).

There are several reasons why the fuel reaching each of the cylinders varies in quality and quantity. First of all, when the throttle valve of the carburetor is partly open, the flow of air and fuel is directed against one side. The choke valve will also affect the distribution. Of even greater importance is that the heavy particles of the fuel mixture have greater inertia than the lighter particles. As a result, the heavier particles will tend to continue moving past a branch in the manifold. The cylinder supplied by that branch will therefore, not receive its full quota of such heavy particles but will receive an excess of lighter particles. Similarly, some cylinders will receive greater quantities of tetraethyl lead than others. Obviously those cylinders receiving the leanest mixture and/or least amount of tetraethyl lead will have the greatest tendency to knock.

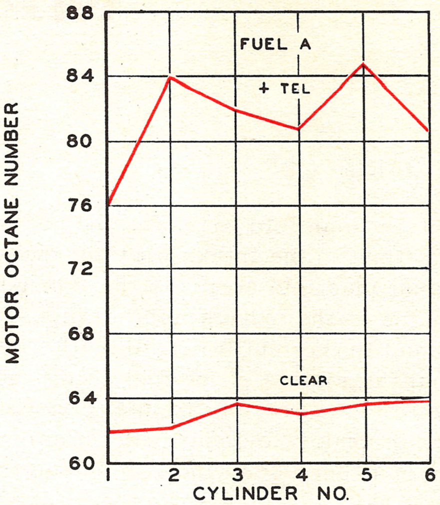
In Fig. 23-2 the variation in air-fuel ratio of the fuel reaching each of the cylinders of a particular manifold is shown and in Fig. 23-3, the variation in the motor octane rating of the fuel supplied each cylinder. It must be emphasized that in addition to the physical characteristics and shape of the intake manifold that the composition of the fuel, the heat supplied, engine speed, etc. will seriously affect fuel distribution.



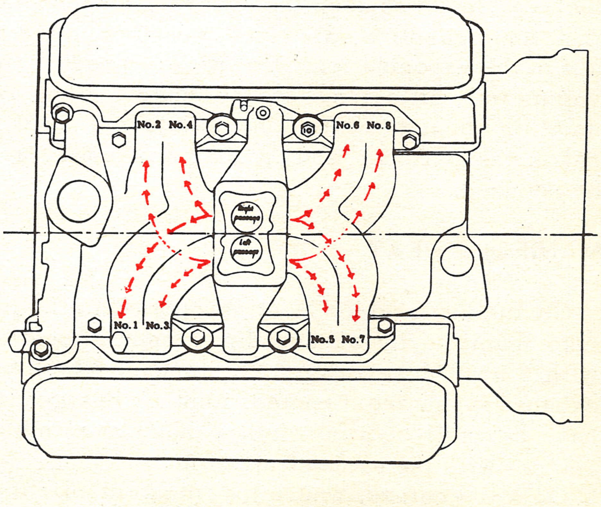
23-2. Note how the air fuel ratio varies in the different cylinders with No. 2 receiving a very rich mixture and cylinders No. 4 and 6 receiving lean mixtures.

From other studies it is learned, that as a result of variations in fuel distribution, explosion pressures developed in a six cylinder engine may vary from a low of 125 lb. per sq. in. to a maximum of 310 lb. per sq. in. In one case it was found cylinders three and four developed the minimum pressure, cylinder six the maximum, and cylinders one, two and five approximately 280 lb. per sq. in. each. Increasing the rate of fuel supply improved the condition up to a certain point, and further increases resulting in cylinders three and four producing an explosive pressure of 310 lb. per sq. in. and the other cylinders developing only 235 lb. per sq. in.

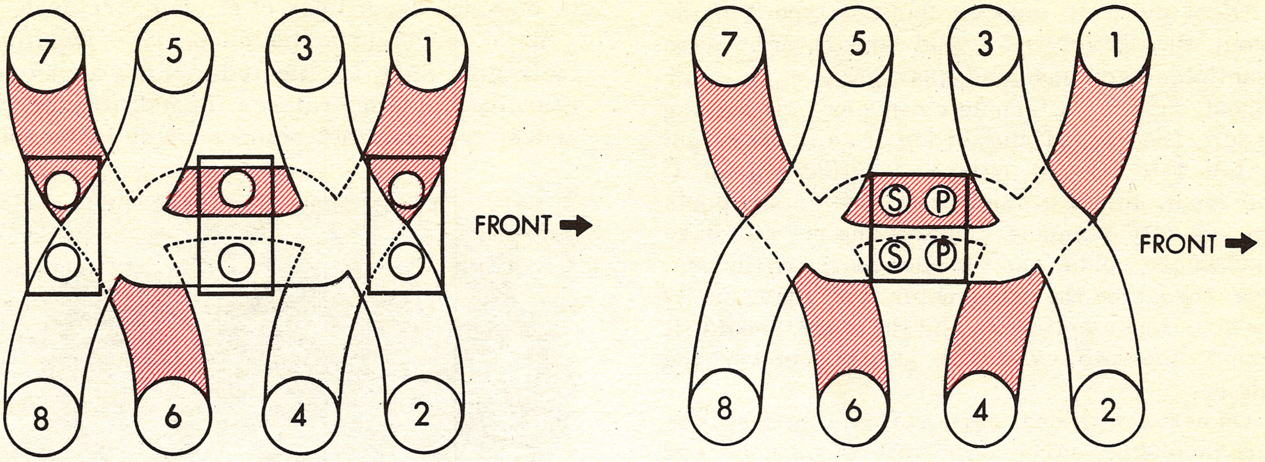
In order to improve the distribution of fuel to the engine cylinders and thereby increase the power, many engines are equipped with carburetors of two or four throats. In addition, some engines will be equipped with more than one carburetor. For example; two four-throat carburetors are often used on V-8 engines. Three dual carburetors have been also used on V-8 engines.



23-3. Illustrating the variation in octane rating of the fuel reaching the different cylinders of a six cylinder engine. The upper curve is for fuel with tetraethyl lead (TEL), while the lower curve is for clear gasoline. Data from experiments made by Sun Oil Co.



23-4. Manifold for dual carburetor on V-8 engine.



23-5. Left. Manifold designed for three dual carburetors on a V-8 engine. 23-6. Right. Four throat carburetor on V-8 engine. The "S" and "P" represent the primary and secondary throats of the carburetors.

Naturally special manifolds have to be used for such installations. In Fig. 23-4, the path of the fuel mixture in a manifold designed for a V-8 using a dual carburetor is shown. A V-8 manifold fitted with three dual carburetors is shown in Fig. 23-5, while Fig. 23-6 shows a more conventional installation of a four-throat carburetor on a V-8 engine.

In order to equalize pressures existing in the two sections of the manifold, it is necessary that they be interconnected. This is usually done by cutting a groove in the flange of the carburetor where it is bolted to the manifold.

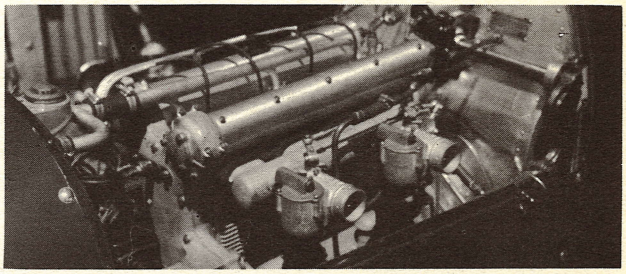
Racing engines or other high performance engines are often fitted with one carburetor for every pair of cylinders. One carburetor for every cylinder has also been used. The carburetor and manifold of a four cylinder Offenhauser racing engine are shown in Fig. 23-7. Note that in this design, the manifold extends beyond the branches leading to the end cylinder.

GENERAL DESIGN OF MANIFOLDS

Manifolds for passenger cars and commercial vehicles are usually made of cast-iron or aluminum while manifolds for racing engines are made either of cast aluminum or built up of aluminum tubing. In other than racing cars the walls of the manifold are approximately 1/8 in. thick.

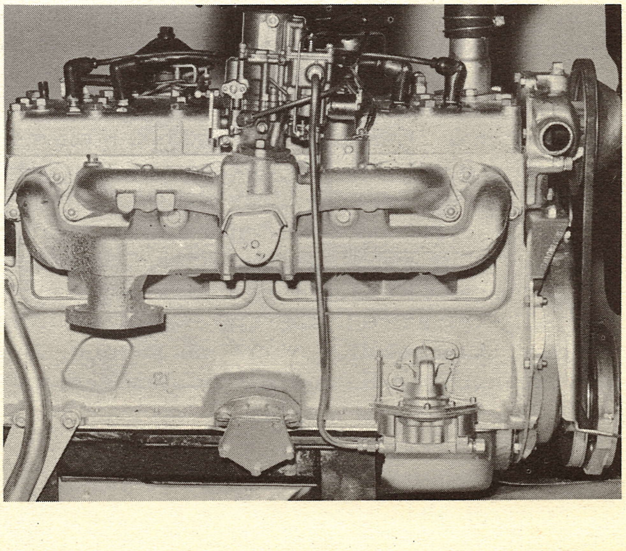
The number of outlets to the manifolds is dependent on the number of cylinders and the arrangement of valves. For example, each cylinder may have its individual intake and exhaust port, Fig. 23-1. A more usual arrangement is to have some of the ports Siamesed, that is, a single port supplies two cylinders.

For example a six cylinder in-line engine may be designed so that both end ports are exhaust and the ends of the intake manifold connect to Siamese intake ports; all other ports, both intake and exhaust, being connected to individual branches of their respective manifolds. With such an arrangement, the exhaust manifold would have six branches while the intake has four. See Fig. 23-8. By having as many Siamese ports as possible, there would be four exhaust ports and three intakes on a six-cylinder engine.



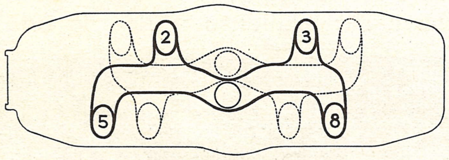
23-7. Offenhauser engine showing the manifold with two carburetors.

23-8. Exhaust and intake manifolding on L-head six cylinder engine.

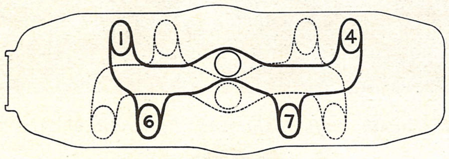


Eight cylinder engines (both V-type and in-line), when fitted with a dual carburetor have the manifolds so designed that each carburetor throat supplies alternate cylinders in the firing order. The usual firing order of an in-line eight is 1-6-2-5-8-3-7-4, number 1 cylinder being at the front. In such engines all the intake ports are usually Siamese and the engine will have four intake ports, one for each pair of cylinders. One throat of the carburetor will then supply the four inner cylinders and the other throat will supply the two cylinders at each end of the engine.

On a V-8 with dual carburetion, Fig. 23-4, one throat of the carburetor will supply the end cylinders on the left bank and the two central cylinders on the right bank. The other throat of the carburetor supplies the central cylinders on the left bank and the end cylinders on the right bank. For example the firing order of the Ford V-8 is 1R, 1L, 4R, 4L, 2L, 3R, 3L, 2R, or 1, 5, 4, 8, 6, 3, 7, 2. One throat of the carburetor will supply 1L, 7L, 6R, and 4R. The other will supply 8R, 3L, 5L, and 2R, Fig. 23-9.



— FIRING ORDER —
LEFT HAND BARREL OF CARBURETOR
5-8-3-2

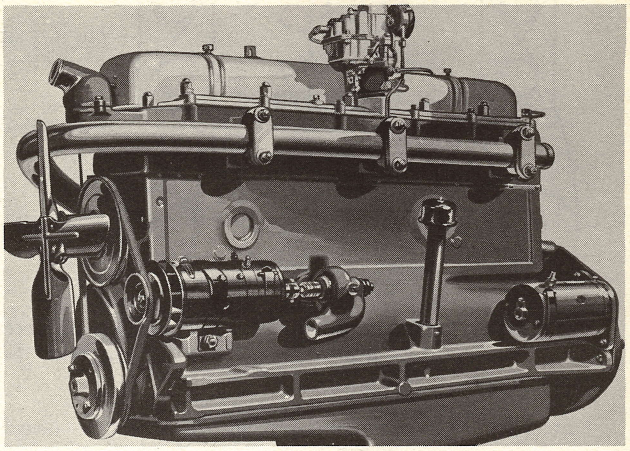


— FIRING ORDER —
RIGHT HAND BARREL OF CARBURETOR
1-4-6-7

23-9. Intake manifolding on Ford V-8 prior to 1949.

The intake and exhaust manifolds on most engines are separate castings, Fig. 23-8. In the case of V-type engines, the intake manifold is placed in the V formed by the cylinders, while separate exhaust manifolds are bolted on each side of the cylinder block. On in-line engines, the two manifolds are placed together on the camshaft side of the engine, Fig. 23-8. However, on some engines, Fig. 23-10, the intake manifold is built into the cylinder block where it is wholly or partly surrounded by water in the cooling system. In this way the temperature of the manifold throughout its length, is maintained at substantially the same temperature, regardless of weather. As a result, carburetion and distribution are improved. Essentially the same economy is obtained regardless of air temperatures.

With conventional bolted-on type manifolds, their efficiency is affected to a degree by surrounding air temperatures. In addition, the front end of the manifold being subject to the blast from the cooling fan, is usually cooler than the rear end of the manifold.

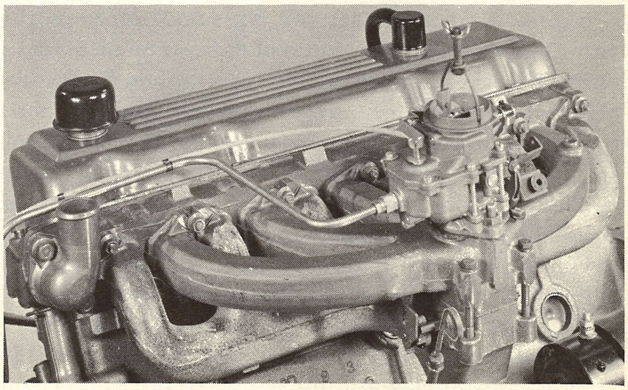


23-10. On the Nash Ambassador, only the exhaust manifold is external. The intake manifold is within the cylinder block. As a result, operating temperature variations are kept to a minimum, and carburetion and fuel distribution are improved.

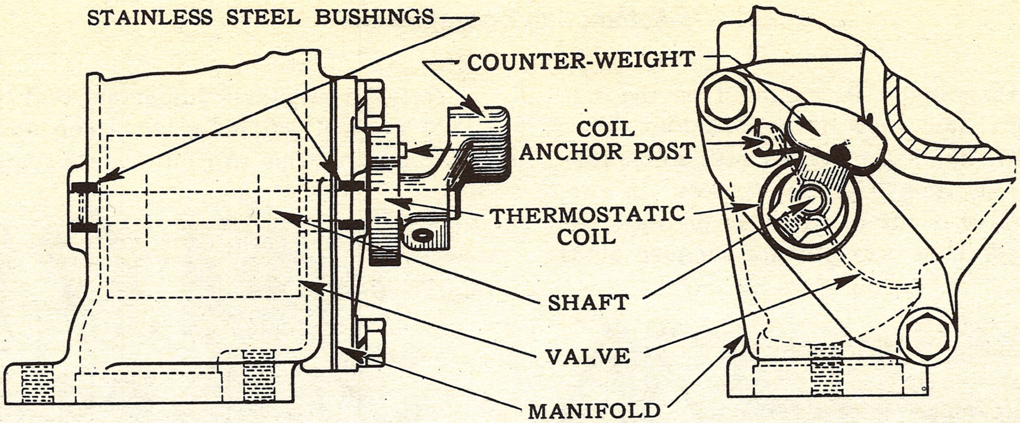
A radical departure from conventional manifold design is shown in Fig. 23-11. In this design, the arms of the manifold make long sweeping curves from the carburetor to the cylinder block. The purpose of the design is to provide more equal distribution of fuel to the individual cylinders, and reduce the variation in octane rating and air fuel ratio of the fuel reaching the various cylinders.

MANIFOLD HEAT CONTROL

The purpose of a carburetor is to deliver a metered amount of atomized fuel mixed with air, to the manifold. However, regardless of how well

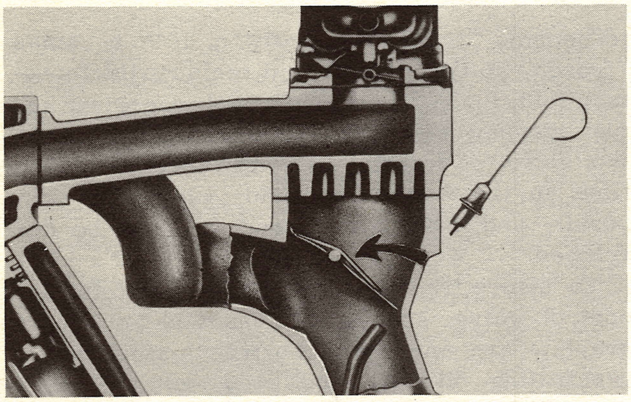


23-11. Note the manifold on this Plymouth engine.



23-12. Details of manifold heat control valve. Note stainless steel bushings and balance weight.

mixed and vaporized the fuel mixture is as it leaves the carburetor, its characteristics are changed as it passes through the manifold. Cold surfaces in the manifold will cause some of the vaporized fuel to condense, and changes in direction of flow will, through inertia, cause some portions of the mixture to settle out. These conditions have been observed by using glass manifolds.



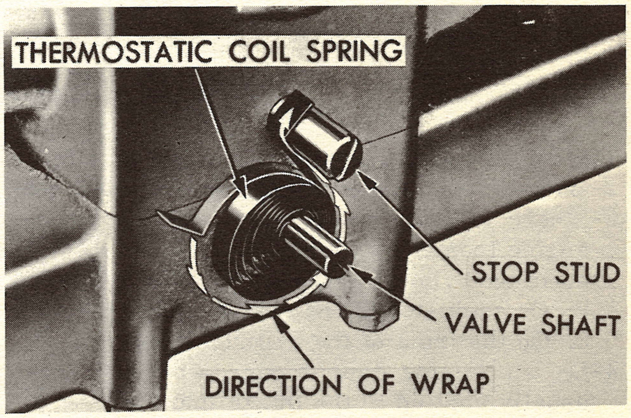
23-13. The manifold heat control valve is indicated by the arrow. It is in the position it assumes when the engine is hot.

The problem is further complicated by the characteristics of the fuel itself. Formerly, when the fuel was highly volatile, the problem was not so difficult. With today's fuels which are relatively non-volatile, it is necessary to supply heat to obtain better vaporization and more equal distribution of the fuel to each cylinder. Heat to the intake manifold is most needed when the manifold is cold, and also when the engine is idling, in which case the suction on the carburetor is low and the fuel is not sprayed very finely. It is important that a minimum of heat reach the carburetor as excess heat would tend to vaporize the fuel before it reaches the carburetor jets, causing vapor lock and flooding.

In order to supply heat to and also regulate the amount of heat reaching the intake manifold, a thermostatically controlled heat valve is installed. Details of such heat control valves are shown in Figs. 23-12, 23-13, and 23-14.

This device known as a manifold heat control valve, is built into the exhaust manifold. It is so designed that when the engine is cold, a maximum amount of heat is directed against an area of the intake manifold. As the engine reaches operating temperature, the thermostat changes the position of the valve, so the exhaust gases are no longer directed against the intake manifold, but are directed directly to the exhaust pipe and mufflers.

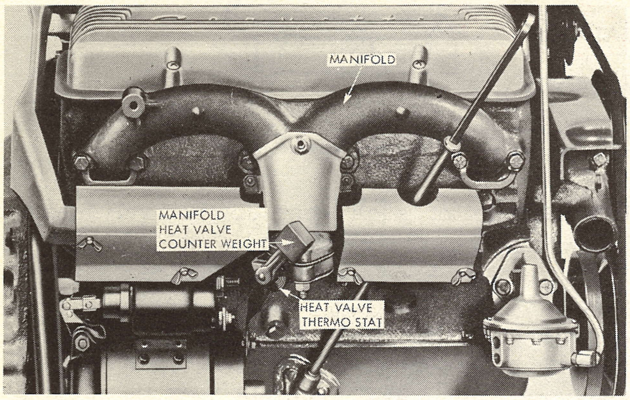
Fig. 23-13, shows the location of a manifold heat control valve on an in-line six cylinder engine. In this case, the valve is in the position it assumes when the engine has reached operating temperature, and the exhaust gases are not directed to the intake manifold, but into the exhaust pipe. With a cold engine, the valve will have rotated in a clockwise direction, directing the gases against the lower surface of the intake manifold. Note how the lower surface of the intake manifold is finned, to increase the area exposed to hot gases.



23-14. Typical thermostatic spring as used to control the position of the manifold heat control valve.

A typical thermostatic coil spring as used on a manifold heat control valve is shown in Fig.

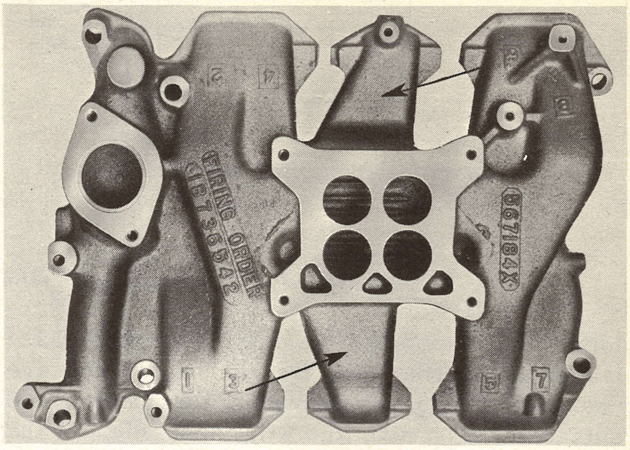
23-14. The thermostat is mounted on the outside of the exhaust pipe or manifold as shown in Fig. 23-15, and is provided with a counterbalance weight, see Fig. 23-12. Note in Fig. 23-12, the valve shaft is mounted on stainless steel bushings. This is important because of the high temperatures and acids of the exhaust, there is a strong tendency for these valves to become rusted in position.



23-15. *Exhaust manifold on side of V-8 engine. Note manifold heat valve.*

In the case of V-8 engines, in order to supply heat to the intake manifold, a passage is provided to carry exhaust gases from one side of the intake manifold to the other. This is known as the exhaust cross over and is shown in Fig. 23-16. The heat control valve, located in one of the exhaust manifolds, Fig. 23-15, then directs the exhaust gases through this cross over passage during the warm-up period.

It is particularly important that the manifold heat control valve be kept free and not rusted in position. Due to rust and corrosion, it is apt to become "frozen" in position. If it becomes "frozen" so that no heat is directed to the intake manifold, fuel will not be properly vaporized and fuel economy will drop. If the manifold heat control valve is "frozen" so heat is directed all the time to the intake manifold, vapor lock will result, and maximum power will not be developed.



23-16. *Arrows point to the exhaust cross over on the V-8 intake manifold.*

To insure free operation of the manifold heat control valve, special oils, usually containing graphite are employed. To free a stuck valve, penetrating oils may be used, and the valve shaft should be tapped back and forth with a light hammer.

QUIZ - ENGINE MANIFOLDS

1-What is the purpose of the intake manifold?

2-Why is heat applied to the intake manifold?

3-Where is the intake manifold on a V-type engine located?
   a. In the V, between the two banks of cylinders
   b. On each side of the engine, on the outside
   c. On the front of the cylinder block

4-On an in-line type engine where is heat usually applied to the intake manifold?
   a. At the center of the manifold
   b. At the rear of the manifold
   c. At the front of the manifold

5-What causes unequal distribution of fuel?

6-Do all cylinders receive fuel of the same octane rating?

7-Which cylinders of a V-8 engine do the barrels of a dual carburetor supply?
   a. Both barrels supply all cylinders
   b. The left barrel supplies the cylinders on the left side of the engine, and the right barrel supplies the right hand cylinders
   c. The right hand barrel will supply center cylinders on the right bank of cylinders and end cylinders on left bank. The left hand barrel will supply the center cylinders of left bank of cylinders and end cylinders on right bank.

8-The manifold heat control valve is designed for what purpose?

9-Why are carburetors of more than one throat used on some multicylinder engines?

10-Why are some intake manifolds built into the cylinder block where they are completely surrounded by water?

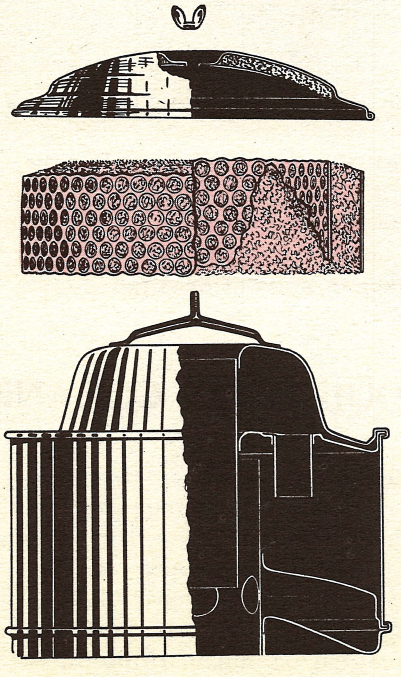
AIR CLEANERS

Air that is drawn into a carburetor and mixed with fuel must be as free from dirt as possible. If this is not done the dust acts as an abrasive and under extreme conditions, the resulting wear will reach such proportions that it soon becomes necessary to recondition the engine.

To reduce the amount of dust entering the carburetor, an air cleaner is installed at the air entrance of the carburetor so all air is screened and filtered. In addition to filtering the air, the air cleaner is also designed to act as a silencer to reduce the noise of the air rushing into the carburetor.

There are several different types of air filters in common use today.

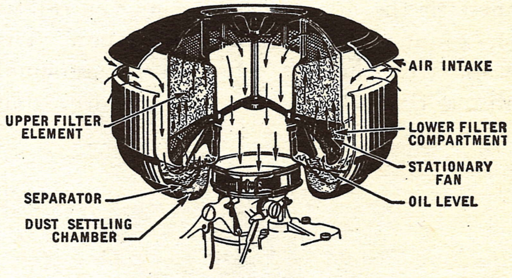
1. Oil wetted mesh cleaner
2. Oil bath cleaner
3. Paper element cleaner
4. Polyurethane cleaner



24-1. Oil filter of the oil wetted, copper mesh type.

OIL WETTED TYPE

The oil wetted mesh cleaner, Fig. 24-1, is one of the older type cleaners. In this design, air passes through a copper mesh screen which has been wetted with engine oil. This type cleaner is not as efficient as some of the others, and has the disadvantage of soon becoming clogged with dust with the further result that air flow is restricted, and the air-fuel ratio is then seriously affected. In addition, relatively large portions of extremely fine dust particles are not removed from the air stream.



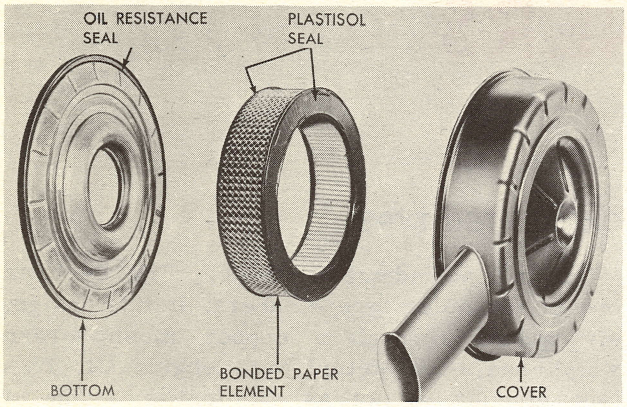
24-2. Oil bath type air cleaner.

Where an oil wetted mesh cleaner is used, it is important that the copper screen be washed in kerosene or other solvent, and then dipped in engine oil at frequent intervals, the frequency depending on dust conditions in the area of operation. Manufacturers recommend that this cleaning operation be done at least every 1000 miles.

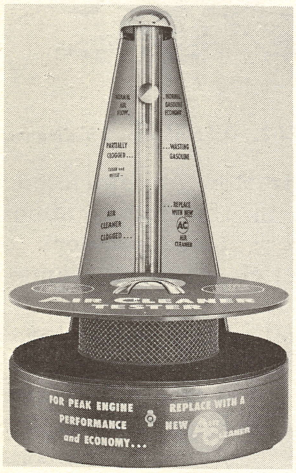
OIL BATH TYPE

In the oil bath type air cleaner, Fig. 24-2, which is more efficient than the oil wetted mesh cleaner, the direction of the incoming air is reversed and directed over the surface of the oil bath. This causes a large portion of the dust to be retained in the oil bath. The air is then passed through an oil wetted copper mesh screen, through the silencer, and into the carburetor.

The usual recommendation for servicing the oil bath type cleaner is to clean it every 5000 miles. The wire-mesh portion of the unit is cleaned in the same manner as the oil wetted mesh cleaner previously described. The oil bath portion of the cleaner is serviced by emptying the oil and scraping the dirt from the bottom of the reservoir. Then the reservoir is refilled with SAE 40 engine oil.



24-3. Paper element, or dry-type air cleaner.



24-4. One form of tester for checking the condition of dry-type air cleaner. Air is forced through the cleaner, and the amount of restriction is indicated by the height of the ball in the tube.

PAPER ELEMENT TYPE

The paper element type cleaner is of more recent development and is highly efficient. The filter element consists of special paper which has been formed into an accordion-pleated ring and sealed top and bottom with a plastic ring, Fig. 24-3. The element can be cleaned by removing it from its housing and tapping it against some hard surface to shake off accumulated dirt. This type cleaner element should never be immersed in cleaning solution. Special testing equipment, Fig. 24-4, is available for testing the element.

POLYURETHANE TYPE

The polyurethane filter, Fig. 24-5, is also a recent development and is highly efficient. The filtering element consists of the polyurethane filtering element which is supported in a perforated metal ring. This element is cleaned after removing it from the housing, by washing in kerosene or mineral spirits. Hot degreasers should not be used. The excess solvent should be squeezed out, and after dipping in engine oil, the filter element is replaced in the air cleaner housing. As the polyurethane element is easily torn, the manufacturers advise that the element should never be shaken, swung or wrung to remove excess solvent or oil.

24-5. Polyurethane type of filter being cleaned in kerosene.

QUIZ - AIR CLEANERS

1-Name four types of air cleaners.

2-Where is the air cleaner installed?
  a. Between the carburetor and the manifold
  b. At the air entrance of the carburetor
  c. On the carburetor air bleed

3-Which type of air cleaner is usually considered to be more efficient, the oil wetted type, or the oil bath type?

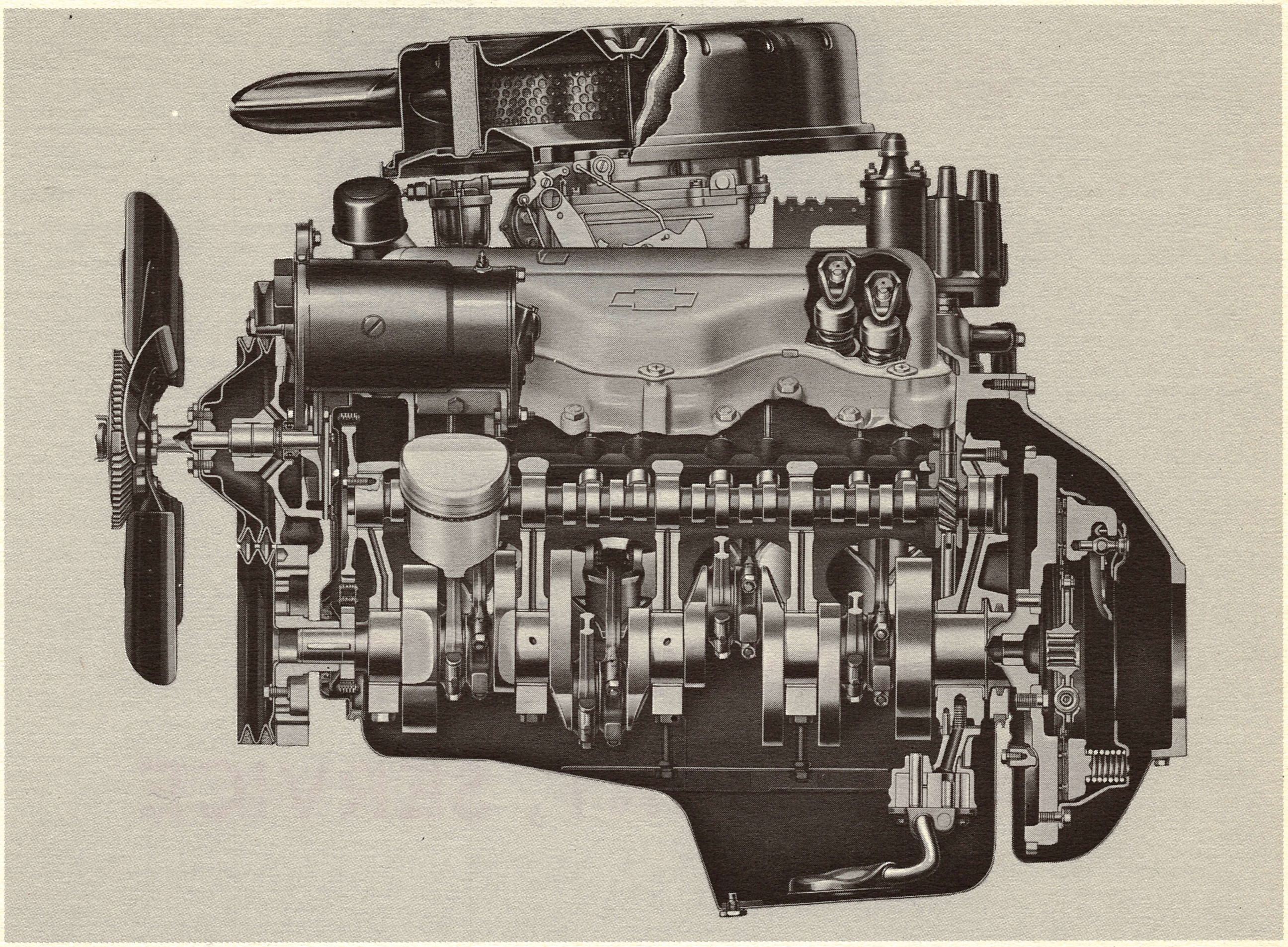
4-What precautions should be taken when cleaning a polyurethane type filter element?

5-How should a paper element type of air filter be cleaned?

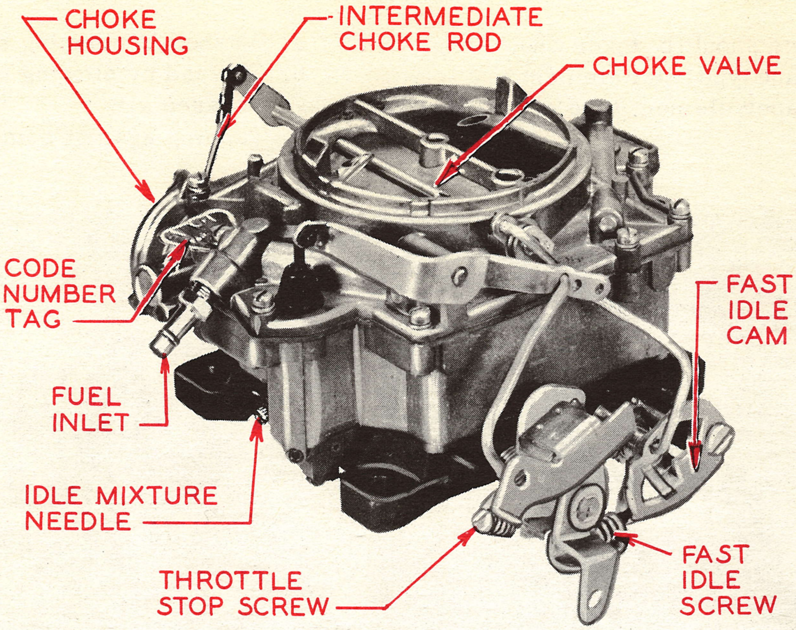
a. Washed in cleaning solvent

b. Cleaned by blowing out the dirt with compressed air

c. Tapping against some hard surface



Chevrolet 409 cu. in. engine with four barrel carburetor. Note oil wetted type air cleaner.



25-1. Showing some of the points that require adjustment on a carburetor. Note particularly the throttle stop screw, fast idle cam and screw, choke rod and idle mixture needle.

CARBURETOR ADJUSTMENT, SERVICE

ADJUSTING CARBURETORS

Modern carburetors are accurately calibrated for the individual engines for which they are designed. Adjustments are provided for idling speed and the amount of fuel required for idling.

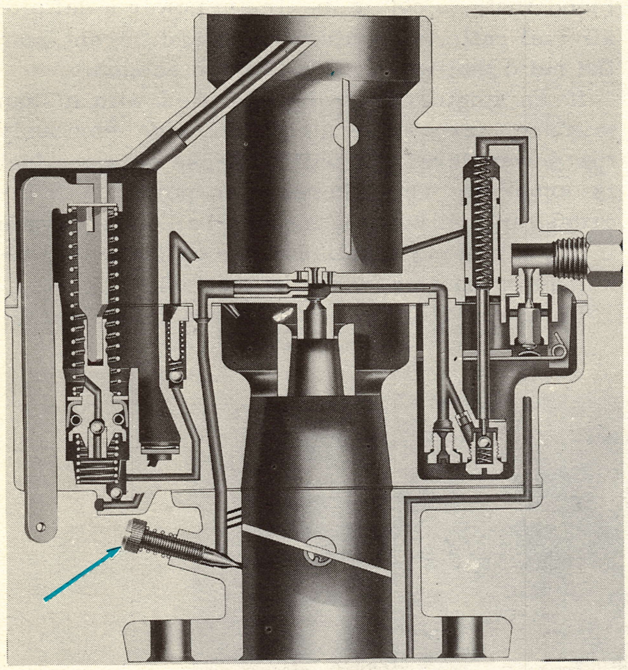
Formerly carburetors were provided with two and three adjustments so that the amount of fuel could be controlled throughout the complete range of engine speeds and conditions. Obviously such carburetors required considerable time and skill to adjust and only a fair degree of accuracy could be attained after prolonged road testing under all speeds and conditions.

Before adjusting any carburetor it is important that the ignition system be in good condition, and that the compression is equal in all the cylinders. It is also important that there be no leaks in the intake manifold, and the engine is at operating temperature. The carburetor must be clean internally, in good mechanical condition, and the float level must be correctly set.

Before attempting to adjust the idle mixture, it is necessary to first adjust the engine idling speed. This is particularly necessary on a vehicle fitted with an automatic transmission, for if the idling speed is too great, the car will tend to "creep" when the engine is idling, and the transmission is in "drive."

To adjust the idling speed, it is necessary to first bring the engine up to operating temperature and make sure the fast idle cam is not holding the throttle open. In addition, the choke must be fully open. With manual-shift cars in neutral, and automatic transmission cars in "drive," adjust the idle speed adjustment screw, or throttle stop screw, Fig. 25-1 to obtain the desired speed. This will vary slightly with different engines. In general, the idling speed for a car fitted with a manual transmission is specified at 475 R.P.M. and automatic transmission at 425 R.P.M.

Today virtually all carburetors, with the exception of some models of the Tillotson carburetor, have an idle mixture adjustment only. On single-throat carburetors the adjustment, indicated by the arrow in Fig. 25-2, is easily and quickly made by turning the adjustment to the position which gives maximum idling speed. Obviously the idle speed or throttle position must not be altered until after the idle mixture has been correctly set. The usual method of making the idle adjustment is to first set it approximately one turn open. With the engine running and at operating temperature, gradually open the adjustment until the engine falters. Then, turn the adjustment in until the engine operates smoothly.

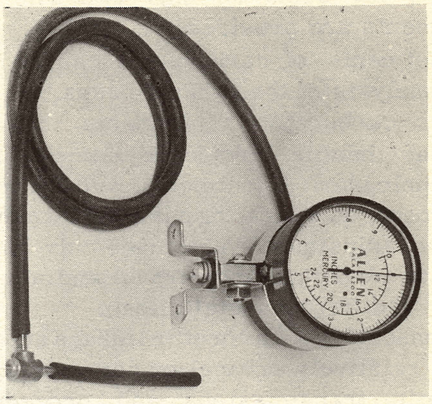


25-2. *The arrow points to the idle mixture adjustment (Rochester carburetor).*

A more accurate method is to attach a vacuum gauge, Fig. 25-3, to the intake manifold and then adjust the idle mixture to obtain the maximum reading on the vacuum gauge. A tachometer, to determine the speed of the engine, may also be used for this purpose.

Many factors, in addition to the condition of the engine, will affect the reading of the vacuum gauge. Compression ratio, carburetor and valve restrictions, and the speed at which the test is made, will all influence the reading. Vacuum readings for tune-up purposes are always made at idling speed.

In connection with engine vacuum readings, it is important to note that the vacuum decreases with an increase in altitude. Approximate vacuum readings for engines of different numbers of cylinders are given in the following table:



25-3. *Vacuum gauge with hose for connecting to intake manifold.*

Elevation in feet	Number of Engine Cylinders Four	Six	Eight
Zero to 1000	18 to 20	19 to 21	21 to 22
1000 to 2000	17 to 19	18 to 20	19 to 21
2000 to 3000	16 to 18	17 to 19	18 to 20
3000 to 4000	15 to 17	16 to 18	17 to 19
4000 to 5000	14 to 16	15 to 17	16 to 18
5000 to 6000	13 to 15	14 to 16	15 to 17

Adjusting two or four-throat carburetors is slightly more difficult, as such carburetors are provided with two idle mixture adjustments. On such carburetors it is advisable to use the vacuum gauge or tachometer method of adjusting the carburetor, as a more accurate adjustment can be obtained.

Before making the idle mixture adjustment on a two or four-throat carburetor, Fig. 25-4, both idle adjustments should be turned in until they seat and then backed out an equal amount. In most cases this should be one turn. Then, after starting the engine and it has reached operating temperature, the two adjustments are turned out equal amounts at a time, until the maximum reading on the vacuum gauge is attained. On most engines the best adjustment will be secured when both idle mixture adjustments are turned out equal amounts. However, in some instances slightly smoother idling will be secured by turning out one adjustment slightly more than the other. There should never be more than one quarter turn difference between the position of the two adjustments.

The procedure for adjusting four-throat carburetors is given with the detailed description of the individual makes. The procedure on such units is the same as only two idle mixture adjustments are provided.

Adjustments of carburetors can be checked by an analysis of the exhaust gases.

Other carburetor adjustments include such items as throttle linkage adjustment, fast idle cam, unloader adjustment, automatic choke adjustment, accelerating pump adjustment. Some of these adjustments are made only in connection with a carburetor overhaul and adjustments vary with different installations.

In connection with throttle linkage adjustment, this is relatively critical on cars equipped with automatic transmissions and procedure and specifications vary with different makes and models. Unless the throttle linkage is correctly adjusted, trouble may be experienced in the shifts of the automatic transmission.

The fast idle cam, Fig. 25-1, must be adjusted in correct relationship to the automatic choke. The final adjustment is such that when the choke is fully open, the fast idle cam should not be holding the throttle open.

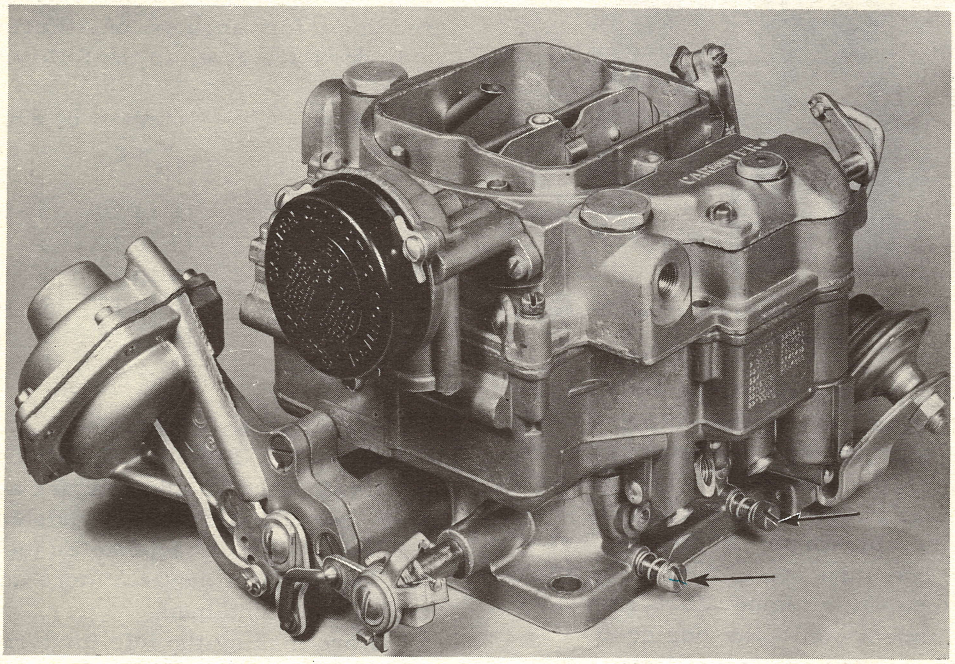
Unloaders are adjusted by means of special gauges on some cars, while on others, simple measurements are used.

EXHAUST GAS ANALYZERS

In the unit devoted to fuels and their combustion, it was pointed out that for perfect combustion of one pound of fuel, 15.27 lb. of air is required. This is the theoretical relationship. However, in an internal combustion engine it is found that, to obtain maximum power a definite air fuel ratio is required which is different from the ratio that will give maximum economy.

If an engine is being operated with a lean mixture, (excessive amount of air), obviously the power developed will increase as more fuel is supplied. This increase in power with increase in fuel will continue until all of the oxygen in the air being supplied to the cylinder is consumed in the combustion of the fuel.

However, the fuel and air reaching the cylinders are imperfectly mixed. The mixture is diluted by exhaust gases that have remained in the cylinder, and the fuel reaching the cylinder ranges from a vapor to wet particles. It is, therefore, necessary to supply more fuel than is called for by theoretically perfect combustion. In general, maximum power is secured from air fuel ratios of 14 to 1, and maximum economy with

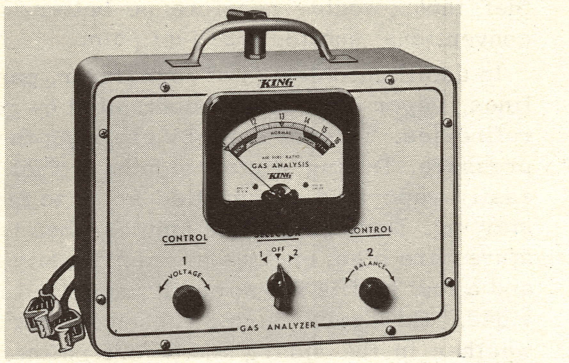


25-4. The arrows indicate the two idle mixture adjustments on this four-throat carburetor. Adjustments on a two-throat carburetor are similar.

ratios of approximately 16-1/2 to 1.

While it is possible to measure the quantities of air and fuel entering an engine, it is a complicated process and limited to research laboratories. The same results can be obtained in the shop with relatively simple equipment, which analyzes the exhaust gases, Fig. 25-5.

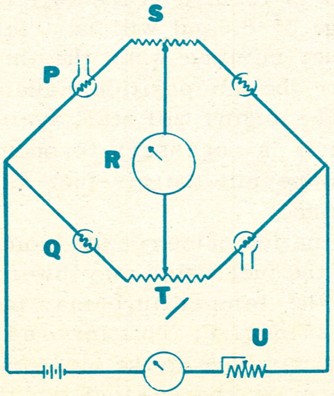
There are several different types of exhaust gas analyzers in use. A frequently used type operates on the principle that the composition of the exhaust gas affects its ability to conduct heat.



25-5. *Exhaust gas analyzer calibrated to read directly in air-fuel ratio.*

Different gases will conduct heat from a heated surface at different rates. That is, their thermal conductivity varies and air is considered as having a thermal conductivity of one. Nitrogen, oxygen and carbon monoxide have a thermal conductivity of approximately the same as air, while carbon dioxide is about one half that of air, while hydrogen is seven times greater.

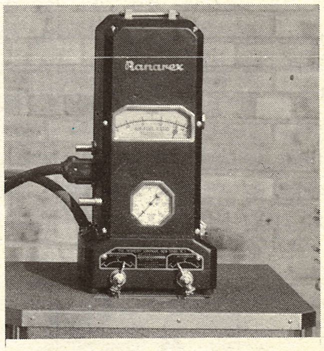
It is this difference in thermal conductivity that is used in the analysis of exhaust gases. To do this, a Wheatstone bridge type of instrument is used, Fig. 25-6. This makes a comparison of the resistance of similar coils of platinum wire, one set of coils being suspended in exhaust gas, while the other is in air. Current is passed through the coils which causes them to heat. The gas surrounding the gas coils conducts away some heat, and thereby affects their resistance, which is indicated on the instrument. The amount or degree of temperature change is dependent upon the composition of the exhaust gas which, in turn, is dependent on the fuel and air entering the engine through the conductor. The instrument can, therefore, be calibrated to read directly the air-fuel ratio.



25-6. *Electrical circuit of exhaust gas analyzer. (P) gas cell; (Q) air cell; (S) inside adjustment; (R) air-fuel ratio meter; (T) balance bridge; (U) balance circuit.*

Hydrogen and carbon dioxide are the components of the exhaust gas that produce the reading on the meter. Hydrogen will cause the pointer to deflect toward the rich side, while carbon dioxide will deflect it toward the lean side.

When using an exhaust gas analyzer, the usual method is to conduct some of the exhaust gas to the instrument by means of suitable tubing. An equally satisfactory method is to place one of the analyzer gas cells in the exhaust tail pipe with electrical connections to the analyzer.



25-7. *Exhaust gas analyzer of the type which weighs the gases, connects to the muffler tail pipe. The instrument also incorporates a vacuum gauge.*

Exhaust gas analyzers are of particular value in checking an engine before and after a tune-up job, as proof, first, of the need for service and then, that efficient combustion has been attained.

They are also of value in determining the efficiency of fuel distribution to the individual cylinders. To make such a check it is necessary to remove the exhaust manifold. The exhaust gas coming from each exhaust port is then analyzed by means of the exhaust gas analyzer. With perfect fuel distribution, the exhaust analysis at each port will be the same. Such tests should be made at different speeds and loads.

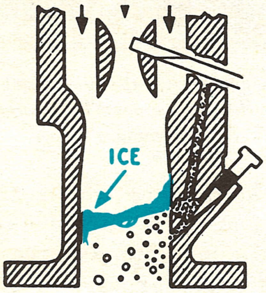
Another type of exhaust gas analyzer is shown in Fig. 25-7. This instrument operates on the principle that the different constituents of the exhaust gas have different weights. A small electric motor is used to drive the mechanism through which the gases pass for mechanical weighing. Some models use 110 volts for the operation of the motor, while others use current from the car battery. The latter type can be used in the car while it is in motion.

VAPOR LOCK

Just as water turns to steam when it is heated, gasoline turns to vapor when sufficient heat is applied. When complete or partial interruption of fuel flow results from vaporization of the fuel, the carburetor system is said to be vapor locked. This condition may occur anywhere in the fuel line, the fuel pump, or in the carburetor itself.

Whether or not vapor is likely to form and cause vapor lock depends on the vapor pressure of the fuel; in other words, the ease at which it will vaporize. The standardized method of measuring or determining vapor pressure in the laboratory is known as the Reid method. U. S. Government specifications for motor gasoline require that the Reid vapor pressure at 100 deg. F. should not exceed 12 lb. per sq. in.

As the vapor of motor fuel occupies a greater volume than in liquid form, the amount of fuel flow will therefore be reduced. Under vapor lock conditions, loss in power and missing will occur and under extreme conditions, the engine will stop. After the fuel and carburetor system has cooled, the engine can be started without difficulty.



25-8. Ice and frost will collect on throttle plate, restricting the flow of fuel from idling jets, when air temperature ranges from 28 to 55 degs. F. and the relative humidity ranges from 65 to 100 per cent.

Carburetors are now designed with vents to overcome or reduce any tendency toward vapor lock. Car and engine manufacturers frequently place an asbestos gasket approximately 1/2 in. thick between the carburetor and manifold. This reduces the transmission of heat to the carburetor so that there is less tendency toward vapor lock in the carburetor. In addition, fuel pumps are placed so that they will be cooled by air blasts and shielded from the heat of the exhaust manifold. Also to reduce the possibility of vapor lock, fuel lines are placed as far as possible from the muffler and exhaust line.

Low pressure on the fuel will also promote vapor lock. A pusher type pump, located in the fuel tank, would therefore be better than the conventional suction type fuel pump.

In addition to design of carburetor, pump, and lines, vapor lock is also controlled by gasoline refineries. This is done by changing the vapor pressure. During winter months a fuel that is easily vaporized is supplied so as to facilitate starting. During summer months when temperatures are high, engines are more easily started and a fuel that is not so easily vaporized is provided. However, during unseasonably warm weather in the spring and before refiners have supplied their summer grade fuel, it is not unusual to encounter difficulties from vapor lock.

CARBURETOR ICING

The formation of ice in carburetors is a problem which will occur under certain weather conditions. It is most likely to occur when the atmospheric temperature is between 28 and 55 deg. F., with the relative humidity between 65 and 100 per cent. It usually occurs after the engine is started and before it has reached operating temperature, and the result is that the engine will stop or stall when operated at idling speed. Each time the engine stops it can be easily restarted, but when the engine speed is reduced to idling it will stop again.

The ice is formed at the edge of the throttle plate, Fig. 25-8, and will restrict the flow of the air-fuel mixture when the throttle plate is at or near the idle position, causing the engine to stop. The engine will start again without difficulty as it is necessary to open the throttle, which will permit the air-fuel mixture to flow to the engine.

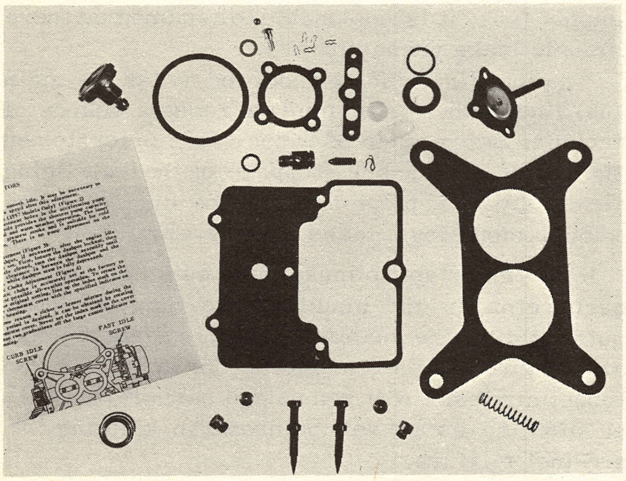
The formation of ice results from rapid vaporization of the fuel which may lower the temperature, or the temperature may be reduced as much as 25 deg. F. This lowered temperature causes the moisture in the air to freeze, causing ice to form on the edge of the throttle plate, where the air speed is greatest.

As soon as the engine reaches operating temperature, the carburetor will be sufficiently warm so that it will be impossible for ice to form.

Fuel refiners use special additives which aid materially in overcoming this trouble. A faster than normal idling speed is of help in minimizing the trouble but adjustment of the carburetor fast idle linkage should be made with care. Many carburetors are now provided with a passage which conducts exhaust heated air around the area of the idle mixture ports, Fig. 21-20. In that way the possibility of carburetor icing is greatly reduced.

CARBURETOR SERVICING

Because of the great number of different makes and types of carburetors in use space limitations here will not permit us to give complete and detailed descriptive procedure on servicing and repairing all these units. However, there are certain basic points which should be observed when overhauling all carburetors.



25-9. ***Parts supplied in a typical carburetor repair kit. Note sheet from illustrated repair instruction folder on left.***

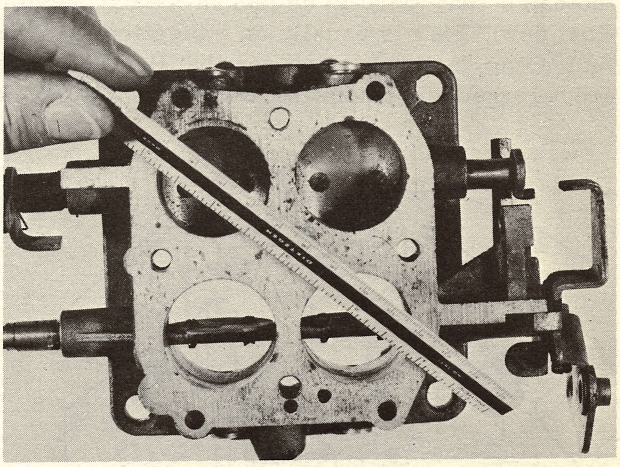
First of all, manufacturers have provided kits of repair parts and gaskets for overhauling their carburetors. See Fig. 25-9. Most of the manufacturers include with those repair kits, the necessary illustrated instructions for replacing the parts.

As the carburetor is being disassembled, all parts should be placed in a convenient tray so that they can be washed in clean commercial carburetor cleaning fluid. All parts should be washed except such items as the accelerator pump diaphragm or plunger, the power valve or power valve diaphragm, and the anti-stall dashpot assembly. In other words, do not wash those parts made of fabric or rubber, which would be injured by the cleaning solution. After cleaning, all traces of the cleaning solution should be washed away with a stream of water, and the parts blown dry with compressed air. Compressed air should be forced through all passages of the carburetor, to be sure they are thoroughly clean. Wire brushes should never be used; neither should fine wire be run through any jets as this may damage the parts.

Check the choke shaft for grooves, wear and excessive looseness or binding. Inspect the choke plate for nicked edges and the choke piston for ease of operation. Make sure the throttle shaft and its bearings are not worn. Worn parts should be replaced.

Inspect all parts such as the air horn throttle body, choke housing, etc., for cracks and other defects. Check all gasket surfaces for warpage, Fig. 25-10. This is particularly important on die castings.

Check the floats for leaks by holding them under water which has been heated to about 200 deg. Bubbles will appear if there is a leak present.



25-10. ***Using a straightedge to check gasket surface of carburetor for warpage.***

Inspect all gasket surfaces for nicks, and replace any parts that have been damaged.

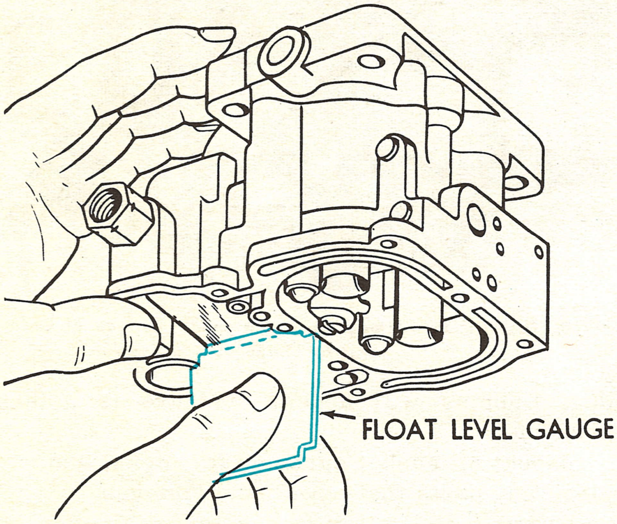
Always install all of the parts contained in the repair kit. Set the float level with the gauge provided, Fig. 25-11.

SHOOTING TROUBLE ON CARBURETORS, FUEL SYSTEMS

Carburetors and fuel systems give many thousands of miles of trouble free service and, while defective or poorly adjusted carburetors will seriously affect the economy and performance of the vehicle, complete failure of the engine to operate seldom originates in the carburetor. Therefore, when the engine does not start or operate efficiently, it is advisable to first check ignition, compression and supply of fuel to the carburetor, before examining the carburetor.

If the ignition and compression prove to be in good operating condition, the first step is to examine the choke to make sure that with the engine cold, the choke is closed and, if the engine is hot, the choke is open. That condition is checked by removing the air cleaner and observing the position of the choke plate which will be visible on removal of the air cleaner.

If the operation of the choke proves to be satisfactory, the next step is to check for fuel to make sure it is reaching the carburetor. This can be accomplished by operating the carburetor linkage by hand. The fuel should spurt from the accelerator jets which can be noted by looking into the carburetor air intake. If no fuel is observed squirting from the accelerator jets, it indicates that there is no fuel in the carburetor float bowl. This is usually an indication that the fuel pump is inoperative, or that the fuel lines are clogged or otherwise defective. To check this condition, disconnect the fuel line at the carburetor and direct the line into a small receptacle. Crank the engine with the starter for a moment. Fuel should flow in spurts from the fuel line into the receptacle.



25-11. Using a gauge to check the float level setting.

A defective fuel pump, or clogged fuel lines or lines with air leaks will prevent fuel from reaching the carburetor, provided of course, that there is fuel in the fuel supply tank. In this connection, the fuel line extends from the top of the tank to within an inch of the bottom. Occasionally this line has broken so it does not reach the fuel unless the tank is virtually full of fuel.

To make sure the line connecting the fuel pump to the fuel supply tank is not clogged or leaking, disconnect it from the fuel pump and force compressed air through it. If the line is clear, the air will be heard bubbling through the fuel in the tank.

AIR LEAKS

Air leaks in the fuel line are more difficult to find and the usual method is to locate the trouble by eliminination. In other words, first make sure the line is not obstructed and the fuel pump is in good condition. If no fuel is pumped from the supply tank, it is reasonable to assume that there are air leaks present.

The fuel line leading from the end of the main fuel line to the fuel pump is a frequent source of trouble. Being made of rubber it deteriorates on the inside and causes stoppage of the fuel. Being flexed by the movement of the engine on its rubber mountings, leaks may develop.

It is important to make sure nuts holding the carburetor to the manifold are tight, and the nuts holding the manifold to the cylinder block are secure. If the carburetor or manifold are loose, air leaks will result and carburetion will be affected as air will be drawn in, diluting the air-fuel mixture.

Troubles with the carburetor itself may be caused by worn linkage, dirt, incorrect fuel level, worn parts, or maladjustment.

Some carburetors are fitted with sight plugs in the side of the float bowl, so the fuel level can be determined without disassembling the carburetor. On such carburetors, the fuel should be level with the bottom edge of the plug hole. Worn external carburetor linkage can, of course, be determined by examination.

Carburetors are usually cleaned by first disassembling and washing the individual parts in special carburetor cleaning solutions. This gives the opportunity of inspecting and replacing any worn parts, and also resetting the fuel level. Special cleaning solutions are available, which will clean the interior of the carburetor while the engine is operating. Such solutions are used by disconnecting the regular fuel line at the carburetor, and connecting a can of the cleaning solution to the carburetor. The engine is then started and operated until a can (usually one pint) of the cleaning solution has been used.

Carburetor cleaning solutions are designed to not only dissolve the grease and dirt that accumulates on the outside of the carburetor, but also the gum which is of varnish-like consistency found on both the inside and outside of carburetors. Such gum is formed by heat acting on the fuel.

CARBURETOR TROUBLE SHOOTING

While the basic causes of carburetor trouble will vary somewhat with different makes and designs of carburetors, the usual conditions or difficulties and their respective causes are outlined as follows:

Possible causes of poor performance generally result from too lean a mixture. If the carburetor is correctly adjusted a lean mixture and poor performance may result from the following:

a. Air leaks at carburetor or manifold
b. Clogged carburetor air filter
c. Clogged fuel lines
d. Defective fuel pump
e. Incorrect fuel level
f. Automatic choke incorrectly set
g. Clogged fuel screen
h. Dirt in carburetor jets and passages
i. Worn or inoperative accelerating pump
j. Wrong or incorrectly set metering rod (Carter Carburetor)
k. Inoperative power valve, economizer or jet
l. Damaged or wrong size main metering jet
m. Worn idle needle valve and seat
n. Loose jets in carburetor
o. Defective gaskets in carburetor
p. Burned through or leaking heat riser
q. Clogged mufflers, ignition and poor compression should also be checked
r. Defective manifold heat control valve
s. Worn throttle shaft
t. Leaking vacuum lines to accessory equipment

POOR IDLING

Poor idling is usually caused by defective ignition system, leaking engine valves, or uneven engine compression. In the carburetor, the following should be checked:

a. Incorrect adjustment of idle needle valve
b. Incorrect float level
c. Sticking float needle valve
d. Defective gaskets between carburetor and manifold
e. Defective gaskets in carburetor
f. Loose carburetor to manifold nuts
g. Loose manifold to block nuts
h. Idle discharge holes partly clogged
i. Defective automatic choke
j. Loose jets in carburetor
k. Leaking vacuum lines to accessory equipment
l. Vacuum leaks which are partly compensated for by a rich idle adjustment
m. Worn main metering jet
n. Restricted or clogged air cleaner
o. High float level

HARD STARTING

In addition to the fuel system troubles listed below, hard starting may be caused by use of engine oil that is too viscous, defective ignition system, low compression, weak starting battery, defective starting motor, excessive friction due to poorly fitted pistons and piston rings.

a. Incorrect choke adjustment
b. Defective choke
c. Incorrect float level
d. Incorrect fuel pump pressure
e. Sticking fuel inlet needle
f. Improper starting procedure

POOR ACCELERATION

Poor acceleration may be caused by defective ignition system, excessive engine or chassis friction, lack of compression, dragging brakes and incorrect carburetion. In the case of the carburetor, the following should be checked:

a. Accelerator pump incorrectly adjusted
b. Accelerator pump inoperative
c. Corroded or bad seat on accelerator bypass jet
d. Accelerator pump leather hard or worn
e. Clogged accelerator jets or passages
f. Defective ball checks in accelerator system
g. Incorrect fuel level

CARBURETOR FLOODS

The usual causes of carburetor flooding are as follows:

a. Fuel level too high
b. Stuck float needle valve
c. Defective gaskets in carburetor
d. Cracked carburetor body
e. Excessive fuel pump pressure

EXCESSIVE FUEL CONSUMPTION

There are many causes of excessive fuel consumption other than defective carburetion. Among such causes may be listed, poor engine compression, excessive engine friction, dragging brakes, misaligned wheels, clogged mufflers, defective ignition. The most usual cause of excessive fuel consumption is quick starts and high speed driving. In the carburetor and fuel system the following should be checked:

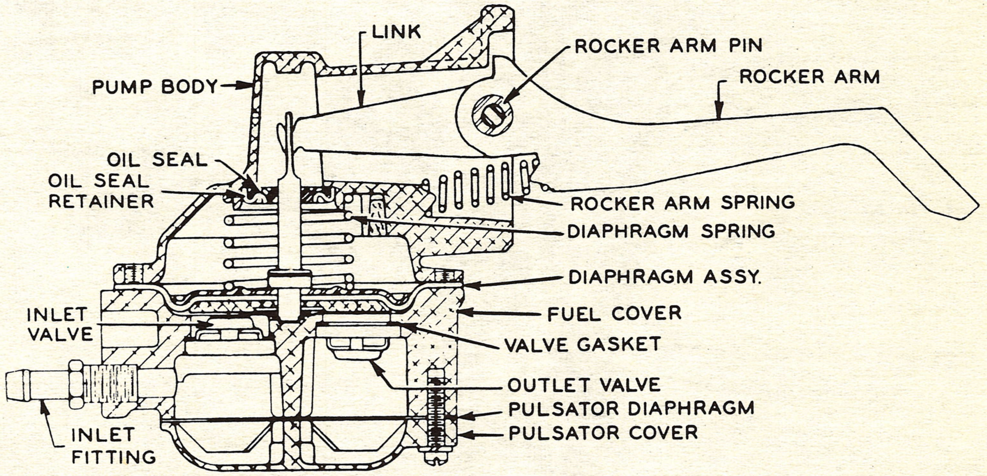
a. Adjustment of idle mixture
b. Fuel leaks in carburetor or lines
c. Clogged air cleaner
d. High fuel level
e. Defective fuel economizer
f. Defective manifold heat control valve
g. Defective carburetor gaskets
h. Defective manifold gaskets
i. Excessive fuel pressure
j. Sticking fuel inlet needle

QUIZ - CARBURETOR ADJUSTMENT, SERVICE

1-Which should be adjusted first?
  a. Ignition
  b. Carburetor
2-How is a vacuum gauge used when adjusting a carburetor?
3-Describe briefly the procedure for adjusting a single throat carburetor.
4-Describe briefly the procedure for adjusting a dual carburetor.
5-With other conditions remaining the same, where would you have the highest manifold vacuum?
  a. In a valley
  b. At the top of a high mountain
6-In general which engine has the highest intake manifold vacuum?
  a. Four cylinder engine
  b. Six cylinder engine
  c. Eight cylinder engine
7-For perfect combustion how many pounds of air are required to burn one pound of gasoline?
  a. 27.15 lb.
  b. 13.50 lb.
  c. 15.27 lb.
  d. 12.75 lb.
8-What is the advantage of analyzing the exhaust gas?
9-Do all gases conduct heat at the same rate?
10-On the Wheatstone bridge type of exhaust gas analyzer, which two gases produce the reading on the meter?
  a. Oxygen and carbon monoxide
  b. Hydrogen and carbon dioxide
  c. Carbon monoxide and carbon dioxide
11-What causes vapor lock?
12-Ice forms at what point in the fuel system when the engine is first started?
  a. Fuel Pump
  b. At the air inlet to the carburetor
  c. At the edge of the throttle plate
  d. In the fuel filter
13-Which of the following parts should not be washed in carburetor cleaning solution?
  a. Carburetor float
  b. Anti-stall dashpot
  c. Idle needle valve
  d. Accelerator pump diaphragm
  e. Accelerator pump plunger
  f. Carburetor float
  g. Throat plate
14-How can a float be checked for leaks?
  a. By inflating with air
  b. Immersing in water at 120 deg.
  c. Immersing in water at 200 deg.
  d. Immersing in gasoline
15-If an engine fails to start and the ignition system is in good condition and the fuel tank is full, what should be checked next?
  a. The position of the choke plate
  b. The idle mixture adjustment
  c. The float level
16-List three causes for carburetor flooding.
17-List three causes for hard starting, which originate in the fuel system.
18-List five causes of excessive fuel consumption originating in the fuel system.

FUEL SUPPLY SYSTEMS

On engines such as used on lawn mowers, and many industrial engines, fuel is supplied to the carburetor by gravity feed. On automobiles, either mechanical or electrical pumps are used. In the case of the mechanical pump, it is operated by means of a cam on the camshaft of the engine. In some cases, the fuel pump is combined with a vacuum pump which is used to operate the windshield wiper. However, in recent years this practice is being superseded by using electric windshield wipers.

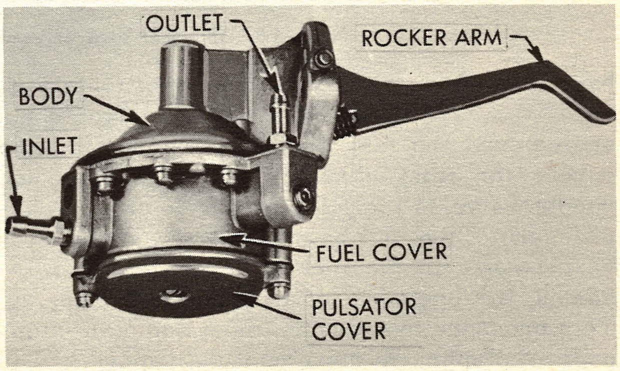

LINK
ROCKER ARM PIN
ROCKER ARM
PUMP BODY
OIL SEAL
OIL SEAL RETAINER
ROCKER ARM SPRING
DIAPHRAGM SPRING
DIAPHRAGM ASSY.
INLET VALVE
FUEL COVER
VALVE GASKET
OUTLET VALVE
PULSATOR DIAPHRAGM
PULSATOR COVER
INLET FITTING

26-1. Typical mechanical type fuel pump. (AC Spark Plug Div.)

FUEL PUMP OPERATION

A typical fuel pump is illustrated in Figs. 26-1 and 26-2. This type of fuel pump has a built-in air dome with a diaphragm to dampen out pulsations in the fuel stream. It is a diaphragm type pump, and is actuated by the rocker arm through a link and pull rod from a cam on the engine camshaft sprocket.

A rocker arm spring holds the rocker arm in constant contact with the eccentric or cam on the engine camshaft sprocket, so the rocker arm moves up and down as the camshaft rotates. As the arm swings downward, it bears against the shoulder on the link which is pivoted on the rocker arm pin. The link swings upward, pulling the diaphragm upward by means of the connecting pull rod. Upward movement of the fuel diaphragm compresses the diaphragm spring, and also creates a vacuum in the fuel chamber under the diaphragm. The vacuum causes the outlet valve to close, and fuel from the gasoline


OUTLET
ROCKER ARM
BODY
INLET
FUEL COVER
PULSATOR COVER

26-2. External view of the fuel pump shown in Fig. 26-1.

supply tank to enter the fuel chamber through the inlet valve.

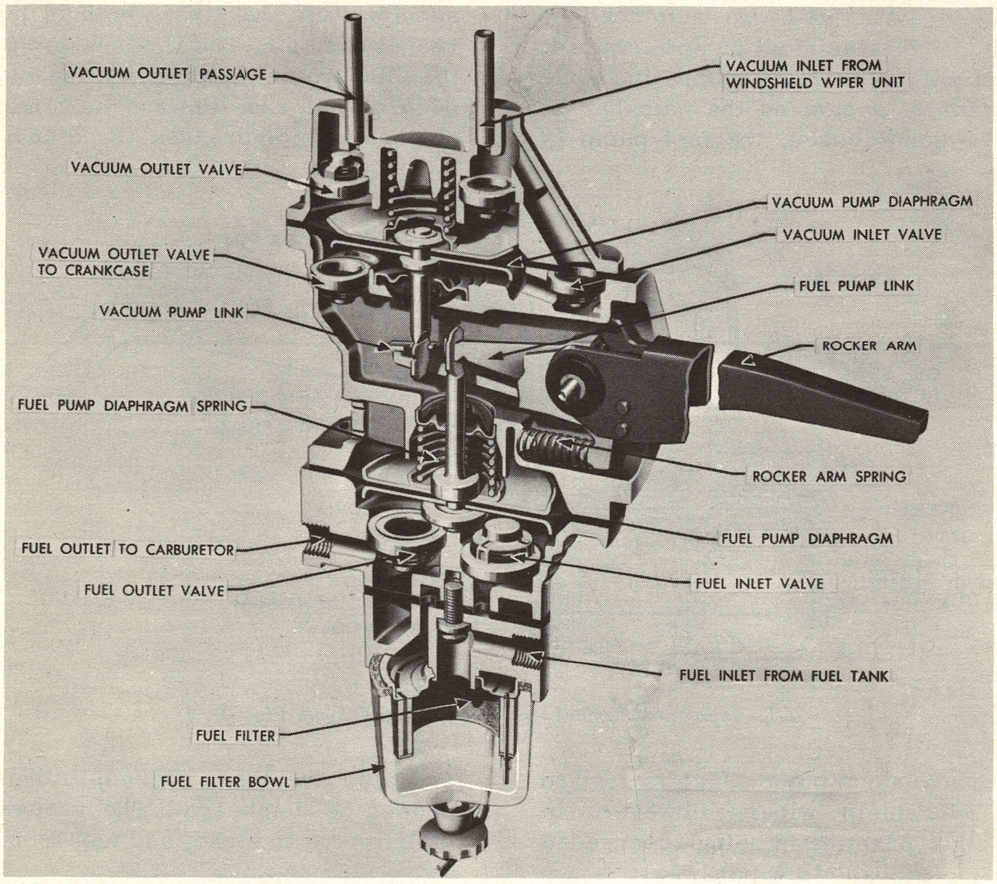
As the rotating eccentric on the camshaft permits the rocker arm to swing upward, the arm releases the fuel link. It cannot move the link downward. The compressed diaphragm spring then exerts pressure on the diaphragm, and the fuel in the chamber below the diaphragm. This pressure closes the inlet valve, and forces fuel out through the outlet valve to the carburetor.

As the fuel diaphragm is moved downward only by the diaphragm spring, the pump delivers fuel to the carburetor only when the pressure in the outlet line is less than the pressure maintained by the diaphragm spring. This condition arises when the carburetor float needle valve is not seated, and the fuel line from the pump to the carburetor float chamber is open. When the needle valve is closed, and held in place by the pressure of the fuel on the float, the pump builds up pressure in the fuel chamber until it overcomes the pressure of the diaphragm spring. This pressure results in almost complete stoppage of diaphragm movement until more fuel is needed.

The air dome with diaphragm in the bottom of the fuel pump provides a pocket in which fuel under pressure can compress a certain volume of air. When the pressure is relieved (pump on suction stroke) the pocket of compressed air pushes the fuel on to its destination. The air dome minimizes flow pressure variations and increases pump output.

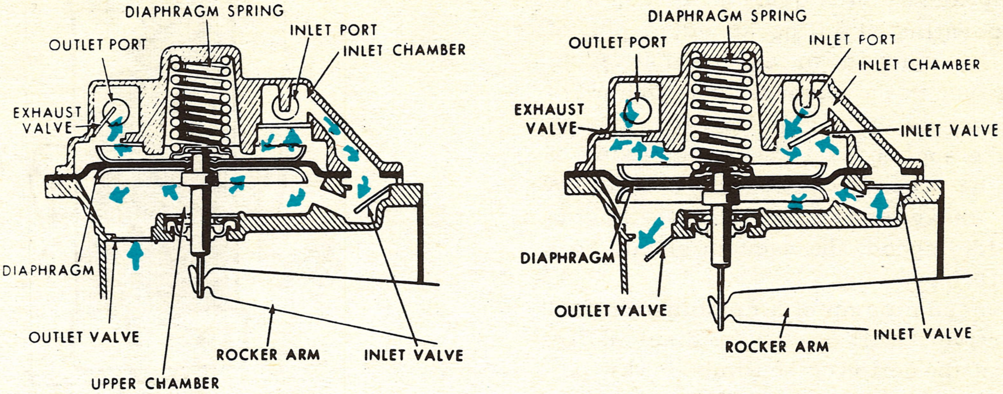
FUEL AND VACUUM PUMP

A combination fuel and vacuum pump is shown in Fig. 26-3. The operation of the fuel section of this pump is similar to the one just described. The vacuum pump section operates as follows:


VACUUM OUTLET PASSAGE
VACUUM INLET FROM WINDSHIELD WIPER UNIT
VACUUM OUTLET VALVE
VACUUM PUMP DIAPHRAGM
VACUUM INLET VALVE
VACUUM OUTLET VALVE TO CRANKCASE
FUEL PUMP LINK
VACUUM PUMP LINK
ROCKER ARM
FUEL PUMP DIAPHRAGM SPRING
ROCKER ARM SPRING
FUEL PUMP DIAPHRAGM
FUEL OUTLET TO CARBURETOR
FUEL OUTLET VALVE
FUEL INLET VALVE
FUEL INLET FROM FUEL TANK
FUEL FILTER
FUEL FILTER BOWL

26-3. Sectional view of combination fuel and vacuum booster pump.

The vacuum booster portion of the pump is shown in Fig. 26-4. As the rocker arm forces the diaphragm up against spring pressure, the outlet valve opens, forcing the air in the upper chamber out through the exhaust port. At the same time a vacuum is created in the lower chamber. This causes air to be drawn from the windshield wiper motor through the inlet port on the booster, into the upper inlet chamber and then through the lower inlet valve into the lower chamber. On the return stroke, spring pressure forces the diaphragm downward expelling the air in the lower chamber through the lower outlet valve. This now creates a vacuum in the upper chamber which again draws the air from the wiper motor into the inlet chamber, and through the upper chamber inlet valve into the upper chamber. This type of vacuum booster makes it possible to supply vacuum to the windshield wiper motor on both up and down strokes of the diaphragm.


DIAPHRAGM SPRING
OUTLET PORT
INLET PORT
INLET CHAMBER
EXHAUST VALVE
DIAPHRAGM
OUTLET VALVE
ROCKER ARM
INLET VALVE
UPPER CHAMBER
DIAPHRAGM SPRING
OUTLET PORT
INLET PORT
INLET CHAMBER
EXHAUST VALVE
INLET VALVE
DIAPHRAGM
OUTLET VALVE
ROCKER ARM
INLET VALVE

PRESSURE CYCLE **RETURN CYCLE**

26-4. Showing details of operation of vacuum portion of fuel pump illustrated in Fig. 26-3.

An exploded view of a mechanically operated fuel pump is shown in Fig. 26-5. Basic operation of this pump is similar to that of the previous pump.

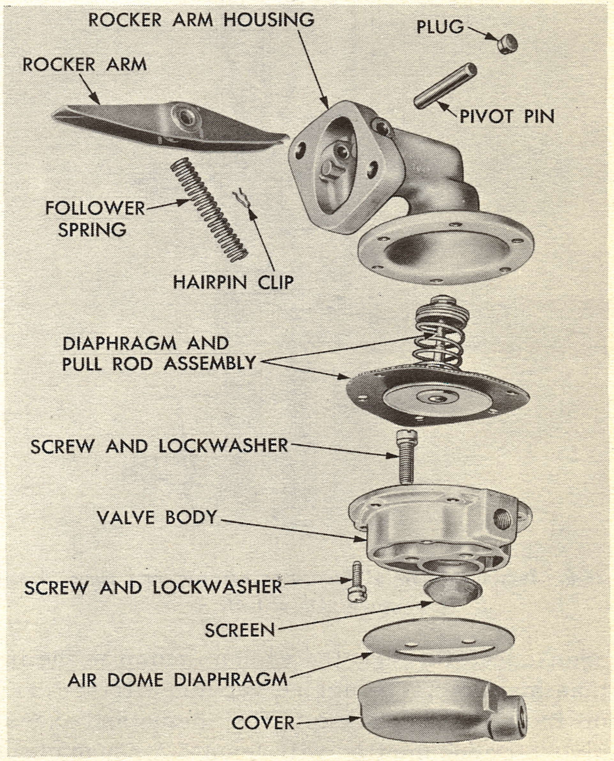
DIAGNOSING TROUBLES OF MECHANICAL FUEL PUMPS

Fuel pumps give many miles of trouble-free service. When they no longer pump fuel in sufficient quantities they should be replaced with a new or rebuilt unit.

To determine if the fuel pump is at fault, first make sure the supply tank has a sufficient quantity of fuel. If the fuel supply is satisfactory, disconnect the fuel supply line at the carburetor, and direct the fuel line into a small container. Then with the ignition turned off crank the engine by means of the starter. If the fuel pump is in good condition, strong spurts of fuel will come from the supply line. If no fuel is pumped or only a small quantity, the pump is probably defective and should be replaced, provided of course that the fuel lines are not clogged, or the fuel line between the pump and the supply tank does not have an air leak. In general, a mechanical fuel pump as designed for passenger car use will pump approximately one quart of fuel in one minute at 500 R.P.M., engine speed.

In this connection, a flexible fuel line is often used to connect the pump with the end of the rigid fuel line leading to the supply tank. These flexible fuel lines, after a year or two of service, may develop air leaks, or the interior may swell and obstruct the flow of fuel.

An infrequent trouble is when the fuel pump supplies too much fuel. Excessive pressures are usually caused by insufficient flexing of the diaphragm. Such a condition would result in flooding of the carburetor.

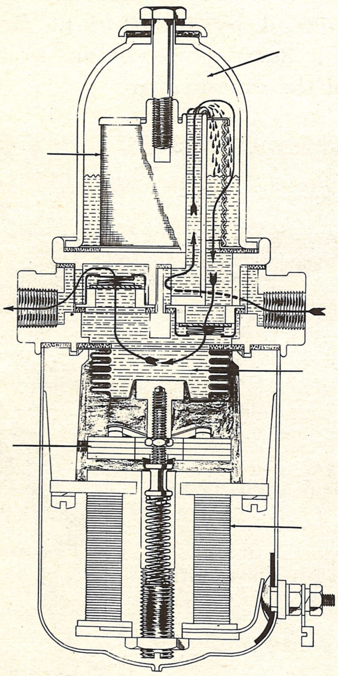

ROCKER ARM HOUSING
PLUG
ROCKER ARM
PIVOT PIN
FOLLOWER SPRING
HAIRPIN CLIP
DIAPHRAGM AND PULL ROD ASSEMBLY
SCREW AND LOCKWASHER
VALVE BODY
SCREW AND LOCKWASHER
SCREEN
AIR DOME DIAPHRAGM
COVER

26-5. Exploded view of mechanically operated fuel pump. (AutoLite)

Fuel pumps may be tested with suitable pressure gauges. The gauge is connected to the outlet side of the pump and, when the engine is cranked by the starter the gauge should register 3 to 5 lbs. pressure. The length of the hose connecting the gauge to the fuel pump should not exceed 6 in., otherwise inaccurate readings may result. Another test can be made by directing the flow from the pump into a pint or quart measure. With the engine operating at idling speed, a pint of fuel should be pumped in approximately 45 seconds. The fuel in the carburetor float bowl is sufficient to operate the engine for a long enough period to make such a test. The vacuum side of the pump can be checked by connecting a vacuum gauge to the intake connection. With the engine operating at idle speed, the vacuum should be a minimum of 10 in.

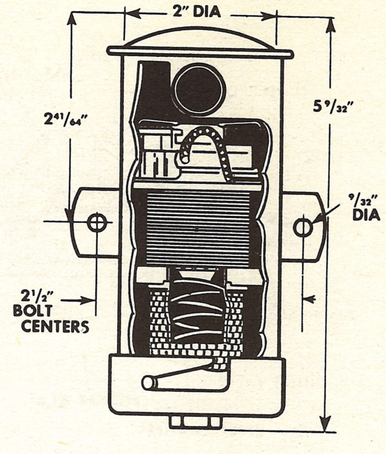
When the vacuum pump of a combination fuel pump is defective it will usually be disclosed by a slowing up of the action of the windshield wiper when the car is ascending steep hills, or whenever the throttle is fully open as when rapidly accelerating.

When the vacuum diaphragm is punctured, there will be a direct line from the engine crankcase, through the vacuum pump to the intake manifold. The engine vacuum will then draw oil from the crankcase to the engine and excessive oil consumption will result. A rough check on this condition can be made by disconnecting the vacuum line leading from the pump to the intake manifold. This should be disconnected at the lower end after the engine has been running for a short period. If oil drips from the tubing the vacuum diaphragm is punctured.



26-6. Sectional view of Autopulse electric fuel pump. Arrows show path of fuel.

Within the fuel pump there are usually five points where wear would affect the performance of the pump. These points are: worn linkage, worn valves or seats, worn pull rod, and punctured fuel diaphragm, and punctured vacuum diaphragm.



26-7. Construction of Bendix electric fuel pump.

ELECTRIC FUEL PUMPS

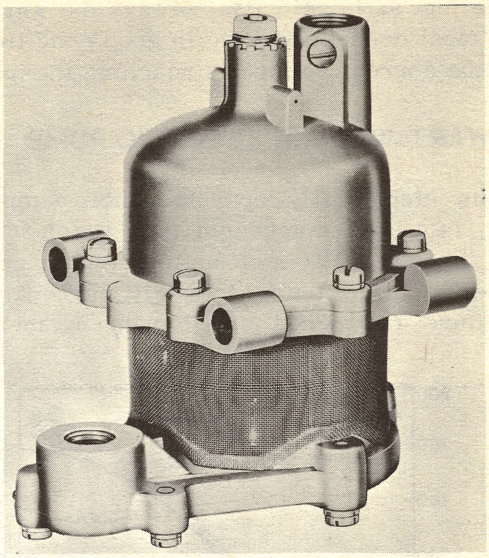
Electrically operated fuel pumps are of two basic types: the suction type which draws the fuel from the fuel tanks in a manner similar to the mechanically operated pumps; and the pusher type pump which is placed in the bottom of the fuel supply tank, and pushes the fuel to the carburetor. Autopulse and the Bendix electric fuel pumps are shown in Figs. 26-6 and 26-7 respectively. Both of these are of the suction type.

An advantage of the externally mounted electric pump which draws the fuel from the supply tank is that several pumps can be installed so, not only can larger quantities of fuel be supplied to the carburetor, but, in addition, in the event that one pump should fail, the others would continue to supply fuel.

An important advantage of the electrically operated fuel pump is that there is a considerable reduction in the tendency toward vapor lock. The reason for this is that it can be mounted on the dash or any other relatively cool spot under the hood. Whereas the mechanical pump, because it is driven mechanically by the engine, will operate at a higher temperature and will therefore be more apt to produce vapor lock. In addition, the electric pump will supply fuel to the carburetor as soon as the ignition is turned on.

The pusher-type pump has the advantage that the fuel in the supply line is under pressure and consequently there is reduced tendency toward vapor lock. There are no valves between the pump and the carburetor and therefore the fuel drains back into the tank when the engine is stopped, thereby eliminating a pressure buildup and consequent hard starting of a hot engine. The delivery of the fuel is steady and non-pulsating.

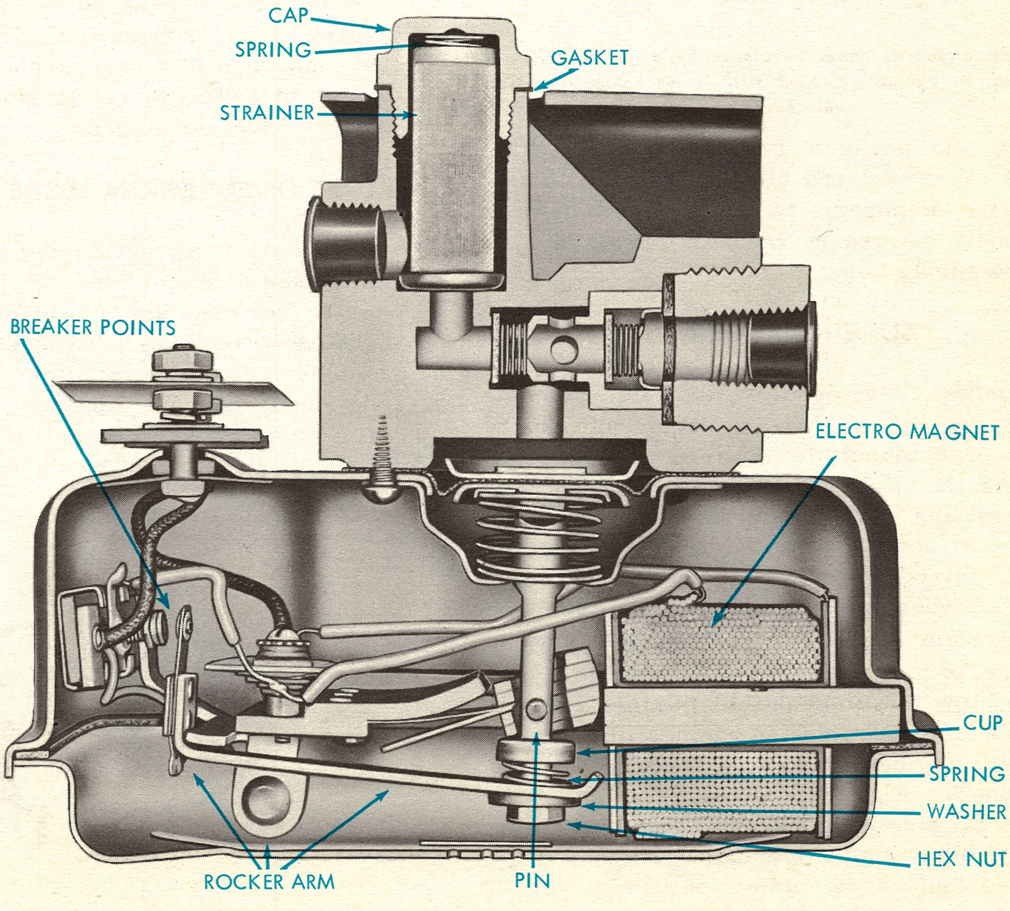
The pusher type unit made by Carter Carburetor Corp., Fig. 26-8, utilizes a centrifugal type unit driven by an electric motor and, being submerged in the fuel, the fuel acts both as a coolant and a lubricant.



26-8. The pusher type fuel pump, developed by Carter Carburetor Corp. is operated by an electric motor and submerged in the fuel in the supply tank. (Copyright by Carter Carburetor Corp. All rights reserved).

SERVICING THE AUTOPULSE

When fuel pump trouble is suspected, disconnect the fuel line at the carburetor, and direct the fuel line from the pump into a small container. Turn on the ignition switch, and then place a finger over the end of the fuel line. If pump stops or clicks very infrequently, the pump and fuel line connections are satisfactory. Remove the finger from the outlet side of the fuel line and, if ample fuel flows, the pump is

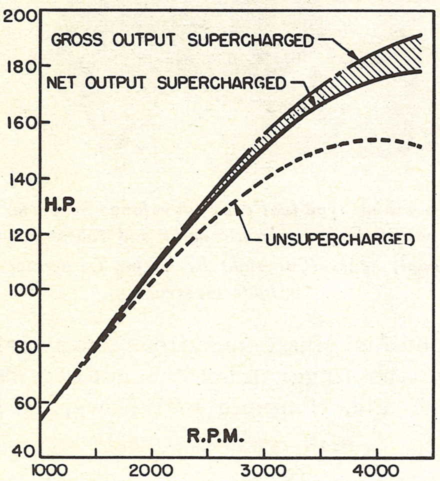


26-9. Details of Stewart-Warner electric fuel pump.

operating satisfactorily. Always be sure that electrical connections are in good condition and that the correct voltage is reaching the unit.

STEWART-WARNER ELECTRIC PUMP

This electrically operated fuel pump, Fig. 26-9, is of the diaphragm type which is operated by the action of an electromagnet and rocker arm and pin. Electric current to the armature is opened and closed by means of tungsten and platinum breaker points. As the current is opened and closed, the rocker arm causes the diaphragm to move up and down to produce the necessary vacuum to draw the fuel from the supply tank.



26-10. Comparison of power developed by a nonsupercharged engine and an engine equipped with a mechanically driven supercharger.

SUPERCHARGERS

The power developed by an internal combustion engine is largely dependent on the amount of combustible mixture reaching the cylinders. Manifolds, carburetors and the size of valves and valve ports are all important factors in determining the amount of combustible mixture reaching the cylinders. In order to overcome the friction losses in the intake system and also to aid in scavenging the cylinders of burnt gases, superchargers are used to blow the combustible mixture into the cylinders of spark ignition engines. In the case of Diesel engines only air is blown into the cylinders. See Fig. 26-10.

Superchargers were first developed for racing cars, and other high performance engines. They have also found wide application on aircraft. In the latter case, the power of an engine falls rapidly as the airplane attains altitude, because of the decreased density of the air. As the air density decreases, smaller amounts of air will be drawn into the cylinders until at an altitude of 18,000 feet only one half the charge will reach the cylinder as at sea level. Only one half the power will therefore be developed under such conditions. Superchargers are therefore used on aircraft to maintain power at high altitudes.

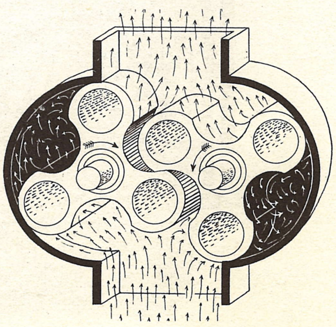
Basically a supercharger is a compressor and a supercharged engine will have a higher over-all compression than it had as a result of the volume of the combustion chamber and the displacement of the cylinder. This higher overall compression will increase the tendency toward detonation of spark ignition engines. When a supercharger is used on an automobile, fuel of higher than standard octane rating is required in order to overcome detonation.

When installed on a Diesel engine, only air is blown into the cylinders and the tendency toward detonation is reduced.

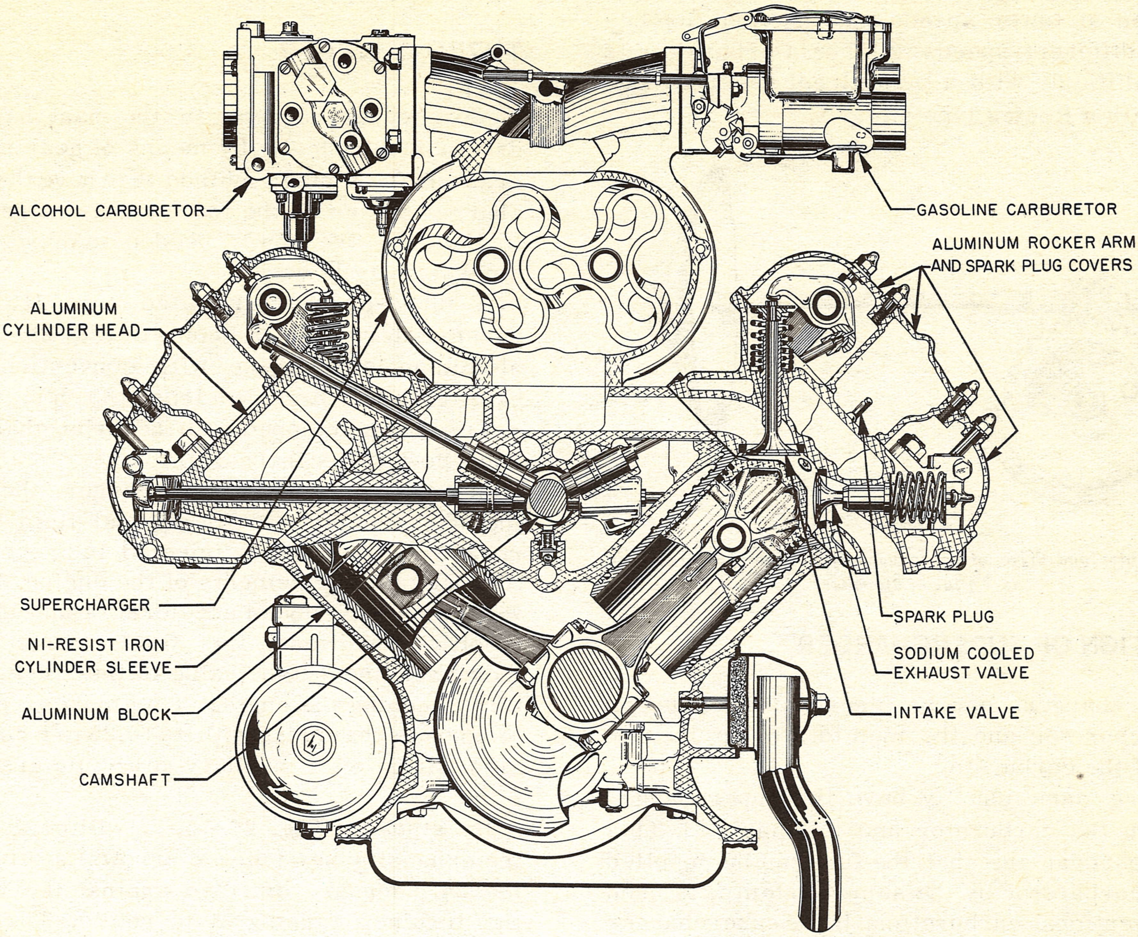
Superchargers are designed to develop from 4 to 20 lb. pressure. Obviously the greater pressure they develop the more mixture or air will be carried to the cylinders. The power required to drive the supercharger increases rapidly, and may be as much as 50 hp. per lb. of air per second. A supercharged engine will burn more fuel than when it is unsupercharged, and the increase in power is not proportional to the increase in fuel consumed.

TYPES OF SUPERCHARGERS

There are two general types of superchargers, the Rootes type and the centrifugal. The Rootes type blower consists of two rotors. In most designs each rotor has two lobes and in shape resembles a figure eight. However, some Rootes type superchargers are fitted with rotors of three or more lobes. A unit with three lobes is shown in Fig. 26-11. The shafts of the two rotors



26-11. Rootes type supercharger.



26-12. Rootes type supercharger installed on Buick XP 300 experimental engine. Carburetors are of aircraft pressure type, one for premium gasoline and the other for methanol. Intake manifold is designed with minimum bends or obstructions to permit easy flow from supercharger to combustion chambers.

are interconnected through gearing and operate at the same speed. Its action is similar to the gear type oil pump. The rotors do not quite touch each other and there is also a slight clearance between the rotors and the surrounding housing. In operation, air enters the housing by the action of the rotors, and passes between the lobes of the rotors and the housing. The air is then forced out through the outlet opening of the unit.

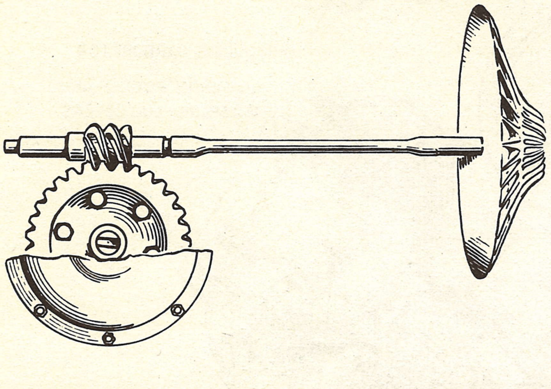
With the Rootes type blower, the rate of delivery varies slightly faster than the speed of rotation, because the leakage decreases as the speed increases. Above a certain minimum speed the amount of supercharging is almost constant. Rootes type blowers are driven at from one to two times engine speed. An installation of a Rootes type supercharger on the Buick XP300 engine is shown in Fig. 26-12.

The centrifugal type supercharger consists of an impeller rotating at a high speed inside a housing. The rotor and drive of a centrifugal type supercharger are shown in Fig. 26-13.

Clearance between the blades and the housing must be kept at a minimum and as speed of rotation is approximately five times engine speed, it can easily attain a speed of 25,000 r.p.m. It is therefore essential that the rotor be accurately balanced, both statically and dynamically. Furthermore, the rotor blades must be made strong enough so that the centrifugal force at high speeds will not cause them to stretch and strike the housing.

On racing car installation, Fig. 26-14, the air from the impeller first passes to a diffuser, where the force of the moving air is converted to static energy. The diffuser consists of a ring-shaped housing containing blades or vanes. Coolers are also used to reduce the temperature of the air. This is important as the act of compressing the air will increase its temperature. The warm air entering would reduce the efficiency of the engine. The coolers consist of several lengths of finned tubing.

The rate of delivery of the centrifugal supercharger increases as the square of the speed of rotation. As a result, very little supercharging is obtained at lower speeds and the variation between different speeds is large. Carburetion is more difficult with a centrifugal supercharger than with a Rootes type unit.

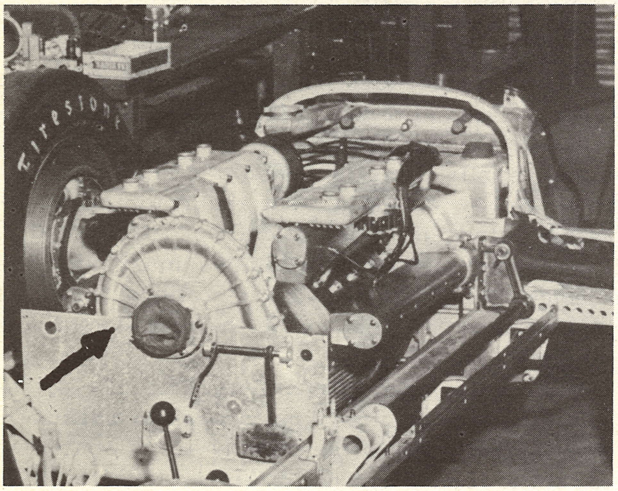


26-13. *Rotor and drive of centrifugal type supercharger. Rotor is 7½ in. in diameter.*

LOCATION OF SUPERCHARGER

Superchargers can be placed either between the carburetor and the manifold or at the air inlet of the carburetor.

Racing cars usually have the supercharger between the carburetor and the manifold. This has the advantage that the fuel can be supplied to the carburetor by the same system as is used in conventional carburetion. If the supercharger is placed ahead of the carburetor, the fuel must be supplied under sufficient pressure to overcome the added air pressure at the carburetor fuel nozzles. When the carburetor is placed between the supercharger and the engine, it is necessary to connect the carburetor float chamber and the outlet side of the supercharger with a pressure equalizing tube.



26-14. *Arrow points to centrifugal type of supercharger intalled on race engine.*

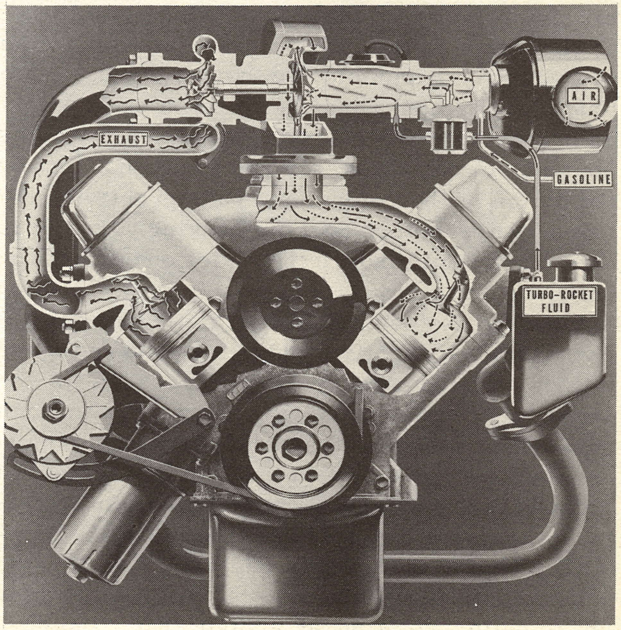
TURBO-CHARGER

Most superchargers in the past have been driven mechanically by means of gearing to the crankshaft. Another method is to have the supercharger driven by the force of the exhaust gases. In that way the power needed to drive the unit mechanically is saved.

A turbo-charger installed on a 215 cu. in. Oldsmobile engine is shown in Fig. 26-15. This aluminum V-8 engine with conventional four barrel carburetor develops 185 h.p. @ 4800 r.p.m. When equipped with the turbo-charger the horsepower was increased to 215.

In addition to the turbo-charger, the design includes the injection of special fluid (Turbo-rocket fluid). This is injected in proportion to the octane requirements of the engine. In other words, during sudden acceleration and under full throttle conditions, this fluid is injected and increases the octane value of the air-fuel mixture reaching the engine. This makes it possible to operate the engine with its 10.25 to 1 compression ration with ordinary premium grade gasoline.

By studying Fig. 26-15, it will be noted that the exhaust gases (curved arrows) after leaving the cylinder are directed against the vanes of the turbine, causing it to rotate. The supercharger is mounted on the other end of the turbo-shaft and forces the air-fuel mixture (dotted arrows) into the intake manifold and on into the

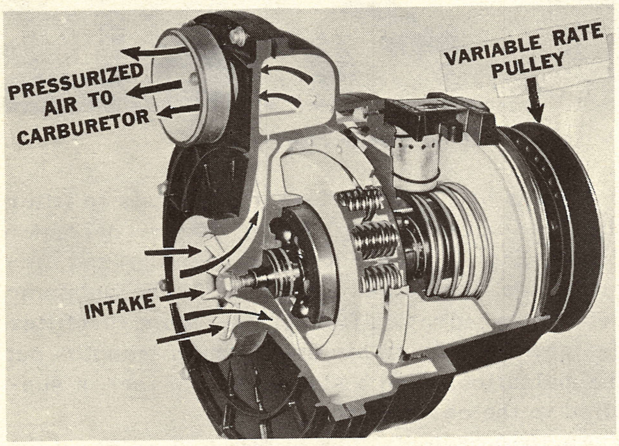


26-15. *Details of turbo-charger as installed on 215 cu. in. aluminum V-8 Oldsmobile engine.*

combustion chamber. The turbo-rocket fuel (solid arrows) is injected into the intake manifold under low vacuum conditions.

STUDEBAKER-PACKARD SUPERCHARGER

The supercharger used on some Studebaker and Packard models gave a five pound boost to the fuel mixture so that approximately 30 per cent more mixture reached the combustion chamber. This supercharger shown in Fig. 26-15 and 26-16 is driven by a variable rate pulley so that maximum power is produced during acceleration while permitting normal fuel economy at cruising speeds. In this design air first passes through the air cleaner, and is then drawn into the supercharger where it is compressed by the impeller which revolves at speeds up to 29,000 R.P.M. The compressed air then passes to the carburetor which is completely enclosed in an air tight housing. During normal driving the variable ratio pulley allows the supercharger to "idle" and the engine operates as a normal power plant. As the accelerator is depressed, the speed of the supercharger is automatically increased so that maximum pressure is developed.



26-16. Details of supercharger and variable rate drive pulley of Studebaker-Packard supercharger.

FUEL GAUGES

There are two general types of fuel gauges in use today; the thermostatic type, and the balancing coil type.

THERMOSTATIC TYPE GAUGE

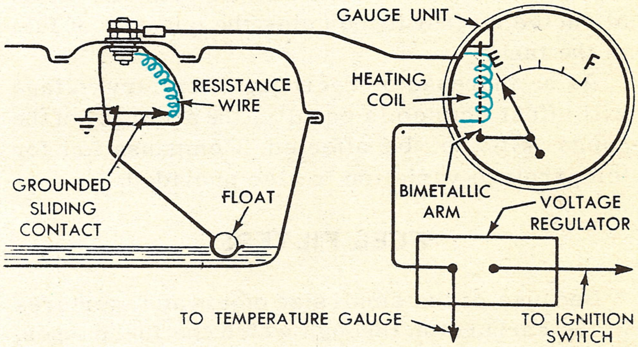
The thermostatic type of fuel gauge consists of a sending unit located in the fuel tank, and the gauge or registering unit located on the instrument panel. In addition, there is a voltage regulator unit which is designed to maintain an average value of 5.0 volts at the gauge terminals. It is compensated for temperature variations and is provided with an adjustment which controls the rate at which the contacts make and break and in that way controls the voltage supplied to the gauge system.

The gauge pointer is controlled by a bi-metallic arm and heating coil, Fig. 26-17. The sending unit in the fuel tank is a rheostat that varies its resistance depending on the amount of fuel in the tank.

When the fuel tank is empty, the grounded sliding contact, Fig. 26-17, is at the end of the resistance wire of the rheostat. With all of the resistance in the circuit, only a small amount of current will flow through the heating coil of the gauge unit, which will then register zero. When the tank is full, the float rises with the fuel, moving the grounded contact toward the beginning of the resistance coil. More current will therefore flow through the heating coil and the bi-metallic arm of the gauge unit will deflect the pointer to the "Full" position.

THE A. C. BALANCED COIL TYPE GAUGE

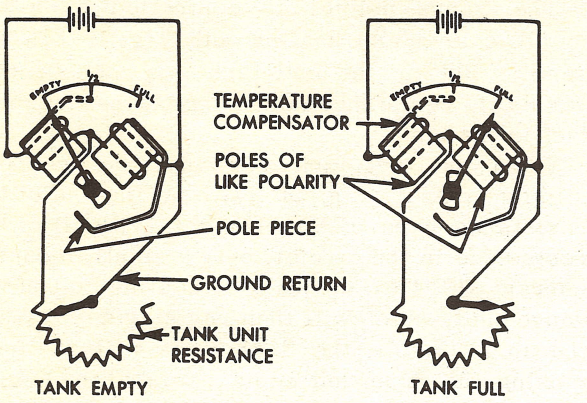
The A. C. fuel gauge used by General Motors cars and trucks as well as some independent manufacturers, is of the electrically operated balanced coil type and consists of a dash unit and a tank unit, Fig. 26-18. The dash unit is made of two coils placed at 90 degs. to each other. An armature and pointer assembly is mounted at the intersection of the center line of the two coils. To prevent vibration of the pointer, the armature is provided with a dampening device.



26-17. Thermostatic type of fuel gauge.

The tank unit of the A.C. fuel gauge consists of a rheostat with a movable contact arm. Position of the contact arm is controlled by a float which rests on the surface of the fuel. To prevent splashing of the fuel from seriously affecting the movement of the float, a torque washer and spring are used.

The tank unit is grounded out of the gauge circuit when the fuel tank is empty and the float is in its lowest position. Current then passes only through the coil on the empty side of the dash unit as the "full coil" is of higher resistance, and the pointer is pulled to indicate zero. As fuel is added to the supply tank, there is corresponding rise of the float. Movement of the rheostat arm places resistance in the circuit, so that current will now flow through the "full" coil. As a result, the pointer will be attracted so that it indicates the quantity of fuel in the tank.

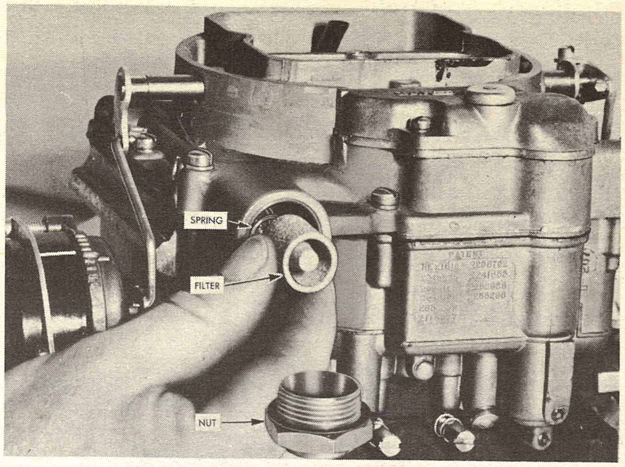


26-18. Circuits of AC fuel gauge. Conditions for tank empty are shown at the left, while full position is shown at the right.

As an increase or decrease of battery voltage will affect both coils equally, the accuracy of the gauge will not be affected. Compensation for temperature variation is also provided.

FUEL FILTERS

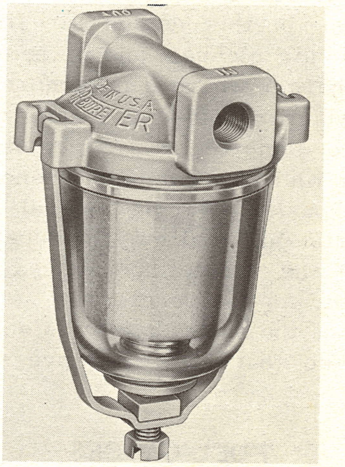
Because of the small size of jets and apertures in the carburetor through which the fuel passes, it is essential that only clean fuel be supplied. Fuel filters are installed in the fuel line between the fuel pump and the carburetor. These filters are of various types and construction and are designed to filter out all solid matter and any water that may be present. Filters are so designed that they can be quickly disassembled and easily cleaned. A strainer of copper mesh is usually incorporated in the design of the fuel pump. In addition, some fuel pumps have effective filters built into the units. In many cases the fuel filter is a separate unit connected in the fuel line between the carburetor and the fuel pump. In a recent design, a ceramic type filter was built in the carburetor, Fig. 26-19.



26-19. Ceramic type fuel filter.

Filters use many different materials to filter the fuel. Ceramic, Fig. 26-20, a series of copper disks, Fig. 26-21; copper screening; and impregnated fibre disks are used. As the fuel pump delivers a pulsating flow of fuel, some fuel filter designs include an air dome which smooths out the pulsations, and a steady flow of fuel is supplied to the carburetor.

As the accumulations of dirt and water in the filter tend to restrict the flow of fuel, it is essential that the unit be disassembled and cleaned periodically. This is usually done twice a year, in the spring and in the fall.



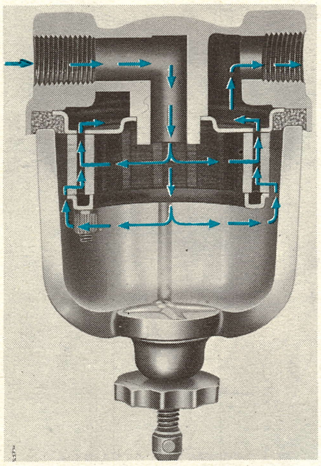
26-20. A ceramic element is used in the Carter fuel filter. (Carter Carburetor Corp.)

Examination of the filter will quickly show how it is disassembled. Frequently the filter bowl is held in place by a bale wire and screw, Fig. 26-22. Loosening the screw will permit slipping aside of the bale wire, after which the filter bowl can be removed, then the filter element. The filter element should be washed in acetone or a good carburetor cleaning solution. Filter elements of the copper disk type should then be blown dry with compressed air. Replacement elements are available in case the original element is damaged or otherwise defective.

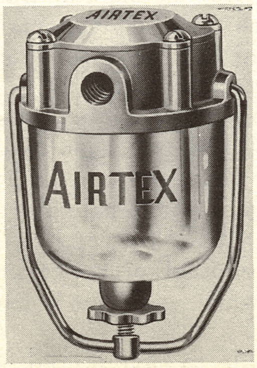
When reassembling a filter it is important to use a new gasket between the bowl and the body of the unit to insure against leakage. If the top of the filter is a die casting, this should be checked for warpage. If found to be warped, a complete new unit should be installed.

LIQUEFIED PETROLEUM GAS

A mixture of gaseous petroleum compounds, principally butane and propane, together with small quantities of other similar gases, is known as liquefied petroleum gas. This is frequently abbreviated as LPG or LP gas. It is used for cooking, heating, and as a fuel for internal combustion engines. In the latter case, it is found principally in large trucks and tractors, as shown in Figs. 26-23 and 26-24.

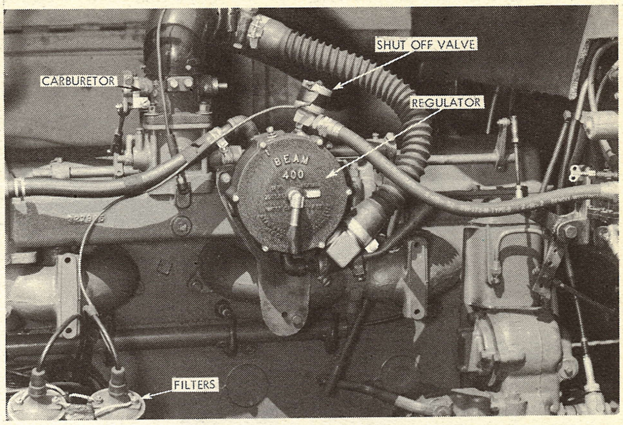


26-21. Illustrating the path of the fuel through a fuel filter produced by AC Spark Plug Div., General Motors Corp.



26-22. Diaphragm type filter produced by Airtex Div. of Cheffort Master Mfg. Co.

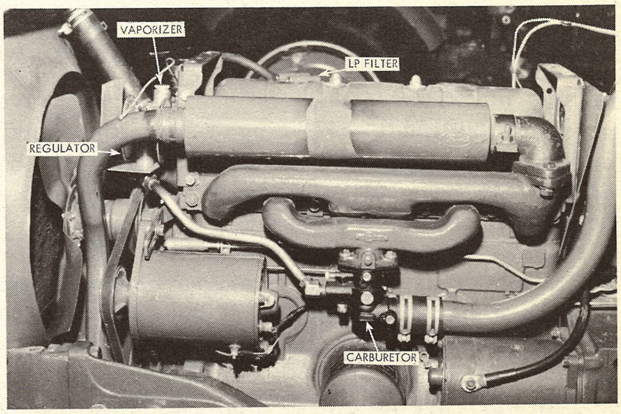
Chemically it is similar to gasoline as it consists of a mixture of compounds of hydrogen and carbon. However, it is a great deal more volatile and at usual atmospheric temperatures it is a vapor. For that reason, when used as a fuel for internal combustion engines, a special type of carburetor is required.



26-23. LPG installation on a truck.

For storing and transporting, LPG is compressed and cooled so that it is a liquid and, depending on conditions, approximately 250 gallons of LPG form one gallon of liquid. Because of the pressure it must be stored in strong tanks. The boiling point of propane is approximately 44 degs. F. below zero.

At temperatures below their boiling points butane and propane exert no pressure, but as their temperature increases, the pressure increases rapidly. For example, at 40 degs. F., liquid propane will have a pressure of 65 lbs., while butane will have a pressure of about 3 lbs. Then at 65 degs. F., the pressure of propane will have increased to 100 lbs. and butane to 15 lbs.



26-24. Zenith LPG system installed on a tractor.

LPG gas is becoming more widely distributed as an increasing number of trucks and tractors are being fitted with the necessary equipment. In addition to its lower cost, LPG has the advantage of having a high octane value. Pure butane has a rating of 93, while propane is approximately 100. The octane rating of LPG will, therefore, range between these two values, depending on the proportion of each gas used.

As it is a dry gas, LPG does not create carbon in the engine and does not cause dilution of the engine oil. Therefore, its use reduces valve grinding, cylinder and ring wear, and other engine maintenance. The oil changes for the engine can be made at less frequent intervals because it is such a clean burning fuel.

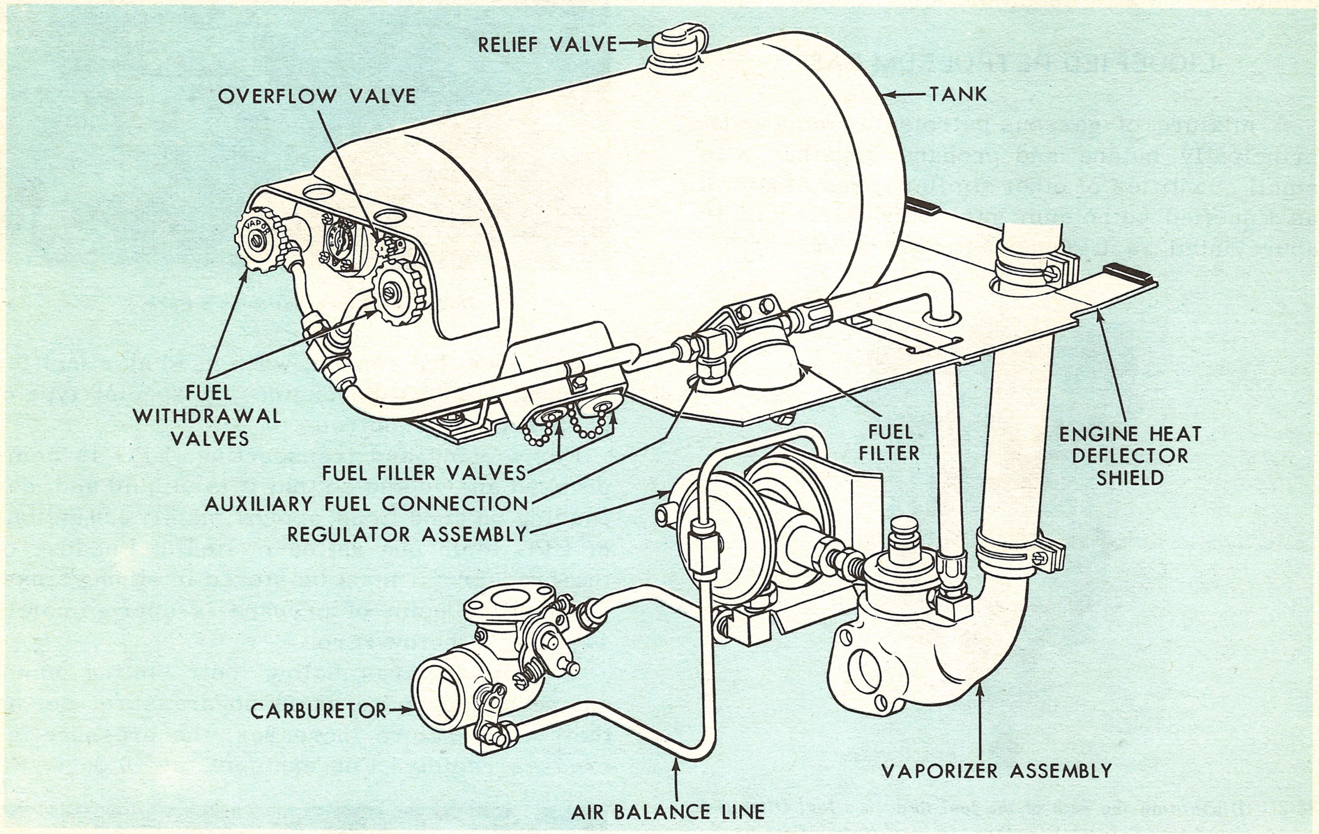
When a standard engine is converted to burn LPG, somewhat less power and reduced mileage may be expected. However, if the compression ratio is increased to take advantage of the high anti-knock rating of the fuel, increased power and mileage are obtained. Engines are now being especially built for LPG operation which are developing superior power and smoothness.

Other advantages claimed for LPG are easy cold weather starting, lack of objectionable exhaust odor, elimination of evaporation, and spillage losses.

This means that a pressure tank must be used and the entire fuel system be kept sealed to avoid loss.

OPERATION OF LPG SYSTEM

Briefly the operation of an LPG system on an internal combustion engine is as follows: The gas leaves the supply tank. Fig. 26-25, as a liquid at high pressure and a vaporizer, or regulator is required to allow this liquid to expand into a gas at low pressure before the engine can use it. These vaporizers are usually mounted near the engine and usually being water jacketed, are connected to the engine water circulation system to avoid frosting of the internal parts in cold weather.

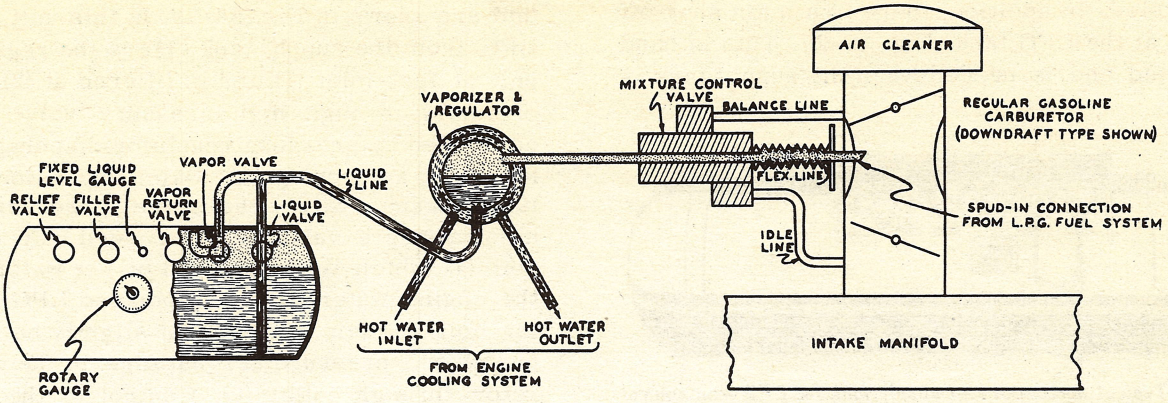


26-25. Layout of Zenith LPG system.

A filter is also connected into the line between the tank and the vaporizer--preferably near the vaporizer to filter out any possible contaminators in the fuel.

From the vaporizer the dry gas, at low pressure, is piped to the mixing valve which is used in place of a carburetor. In Fig. 26-26, the conventional gasoline carburetor has been converted to use LPG. The engine starts and operates under control of the throttle valve, just the same as when gasoline is used in a carburetor.

It is desirable to have a cold intake manifold when using LPG so the manifold heating arrangements are usually blocked off.



26-26. Schematic drawing of LPG carburetion system. This system, designed by the A. O. Smith Co., converts the conventional gasoline carburetor to use LPG.

Equipment is available for installation on conventional automotive engines which were originally designed for operation with gasoline. To take full advantage of the high octane value of LPG, the compression ratio of the engine should be approximately 10 to 1. The ratio will depend to some extent on the contour of the combustion chamber.

Some equipment is designed so the engine can be operated on either LPG or gasoline. This is accomplished by means of push-button controlled solenoid valves, one in the gasoline line and another in the LPG line.

Other equipment is available which replaces the carburetor on a gasoline engine, so operation is on LPG only. In addition, some engines are designed specifically for LPG and naturally such engines take full advantage of the fuel.

LPG CARBURETOR SYSTEMS

The differences between the LPG and gasoline carburetion systems are basically mechanical and arise from the different characteristics of the two fuels.

As LPG in the supply tank is under pressure, a fuel pump is not required. Being under relatively high pressure, the fuel first passes through a pressure reducing regulator which operates from a coil spring working against a diaphragm. This regulator reduces the pressure to between 10 and 3 lbs. per sq. in.

From the primary regulator, the LPG passes to the secondary regulator which is also a diaphragm type regulator. Because of reduced pressure, the fuel reaching the secondary regulator is a vapor and the secondary regulator reduces the pressure so that it is the same as atmospheric pressure, and the fuel is delivered to the carburetor where it is mixed with the correct proportion of air.

There are two main types of LPG carburetion systems. One system, known as the vapor withdrawal system, takes the vapor from the top of the supply tank. The other type draws liquid fuel from the bottom of the supply tank and is known as the liquid withdrawal system.

In the tank vapor system all regulators operate on gas, while in the liquid withdrawal system, the first regulator works on liquid, with the second on gas. Liquid withdrawal systems include a positive action vaporizer. This unit is supplied with heat from the engine.

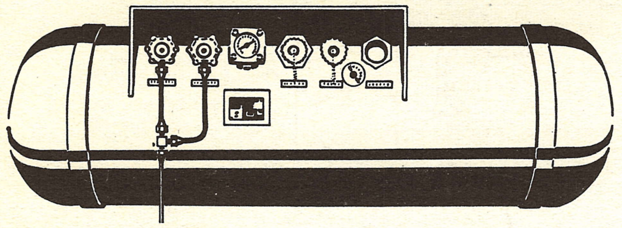
On some gasoline engines that are converted to LPG, the original carburetor is used. In such cases the carburetor body is drilled and a tube is inserted into the venturi. The location of the opening of the tube corresponds to the opening of the main discharge. A similar arrangement is used on installations designed to operate on either gasoline or LPG.

Another design known as the adapter type carburetor, consists of an air-fuel mixing unit. This is installed between the gasoline carburetor and the air cleaner. No throttle plate is provided in the adapter carburetor, as the throttle on the gasoline carburetor is used. A disadvantage of such a design is that on conventional passenger cars, there is seldom enough clearance to permit such an installation. However, it does eliminate altering the carburetor as does the former design.

Some manufacturers are producing special combination carburetors which permit switching from gasoline to LPG as desired by the operator.

However, to take full advantage of LPG (as was previously pointed out) a compression ratio of approximately 10:1 is desired.

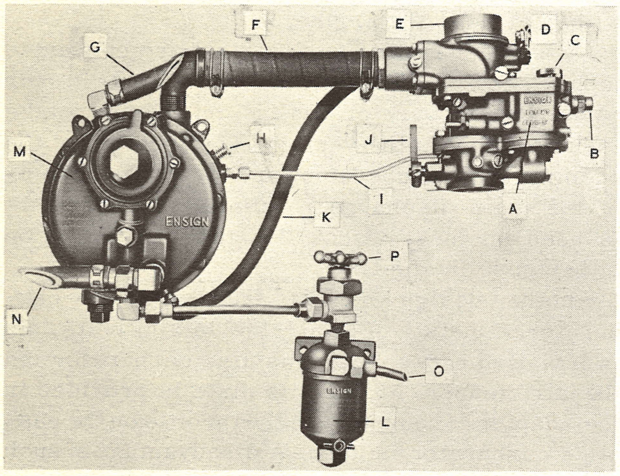
Obviously when a conversion installation is made which permits operating on either gasoline or LPG, special shut-off valves are installed as both fuels cannot be used simultaneously. These valves may be either manually or electrically controlled. In addition, there is a main shut-off valve at the LPG tank. Fig. 26-27. This is hand operated and is needed when the supply tank is filled.



26-27. *Typical horizontal fuel supply tank for LPG with control valves and gauges.*

A combined vaporizer and pressure reducing device is shown in Fig. 26-28. This device takes the liquid butane-propane under tank pressure, and converts it into a dry gaseous fuel at slightly below atmospheric pressure, and regulates the flow of this gas through the carburetor in the correct volume and pressure to meet the demands of the engine at all speeds and loads.

In Fig. 26-28, the various parts are as follows: (A) Combination LPG and gasoline carburetor; (B) Gasoline inlet to carburetor; (C) Gasoline float lock; (D) Easy starting choke; (E) Air inlet to carburetor; (F) Connection between LPG regulator and carburetor carrying LPG vapor; (G) Hot water supply from engine water jacket to supply heat to regulator M; (H) Idle adjusting screw on regulator; (I) Supply line for idling mixture; (J) Carburetor throttle lever; (K) Balance line; (L) Filter for LPG; (M) Ensign regulator unit type R; (N) Water return line to pump; (O) LPG line to supply tank; (P) LPG shut-off valve.



26-28. *The Model-R Ensign regulator unit is a combined vaporizer and pressure reducing device.*

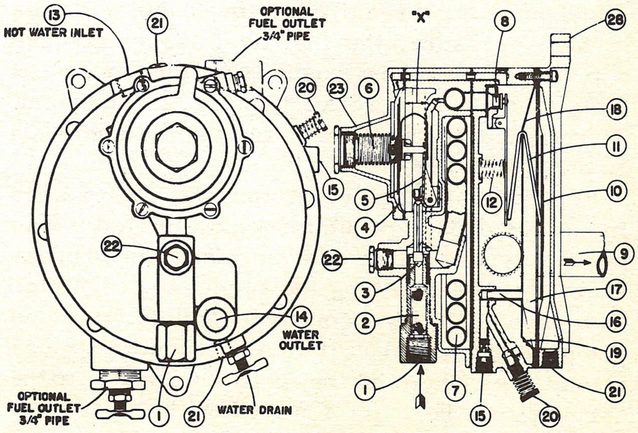
Details of the Ensign model R LPG regulator unit are shown in Fig. 26-29. In this unit, liquid LPG from the supply tank enters the regulating unit at fuel inlet (1) and is filtered at (2). Flow of liquid through high pressure valve (3) is controlled by pressure regulator diaphragm (4), lever (5), and spring (6). Major expansion of the liquid occurs within the space surrounding the high pressure valve (3). Expanded LPG enters coil (7) which is surrounded by hot water from the engine water jacket. Vaporized LPG leaves the coil at main valve (8) at slightly below atmospheric pressure for passage to the carburetor through outlet (9). Control of the outlet pressure is accomplished by operation of the large regulator diaphragm (10), lever (11), and spring (12).

Hot water from the engine cooling system enters the regulator at (13). Hot water then flows over the vaporizer coil (7) through outlet (14) and back to the intake side of the engine water pump.

LPG for idling is taken at (15), via tube (16) from the LPG vapor reserve chamber (17) which is located behind partition plate (18). Fuel enters this zone through orifice (19) and the idle adjustment is made at (20).

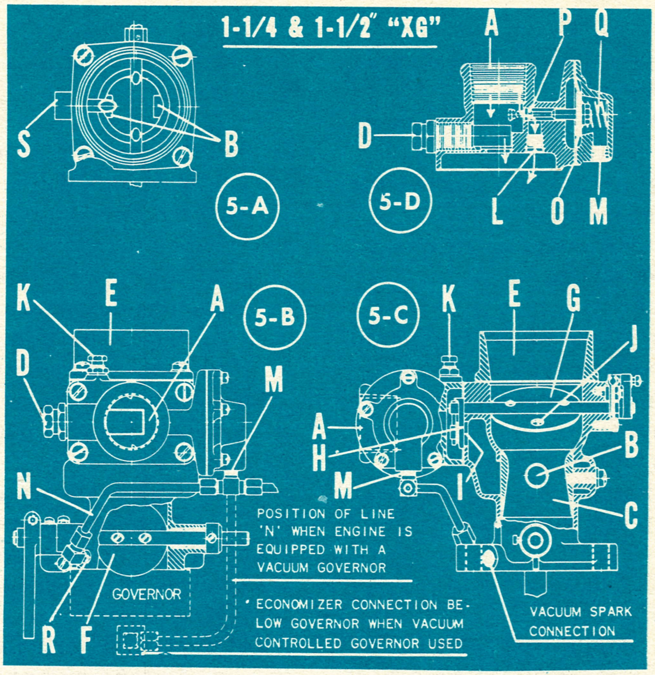
An atmospheric vent (21) on back cover plate behind diaphragm (10) is connected to the carburetor air horn pitot tube and is known as the balance line. Its purpose is to automatically reduce the flow of LPG vapor from the regulator unit to compensate for air cleaner or other air entrance losses.

Details of a carburetor for LPG gas only are shown in Fig. 26-30. LPG enters at (A) at slightly lower than atmospheric pressure from the regulating unit. Gas flows through nozzle (B) into venturi (C) and is regulated by the main gas load adjusting screw (D). Air enters the carburetor air horn (E) and mixes with the LPG in the venturi (C) and passes on to the intake manifold



26-29. *Details of LPG regulator produced by Ensign Carburetor Company.*

of the engine. The throttle plate (F) controls the volume of combustible mixture reaching the engine. The LPG idle line from the regulator is connected at (R) on the carburetor and the idle adjustment is made on the regulator.

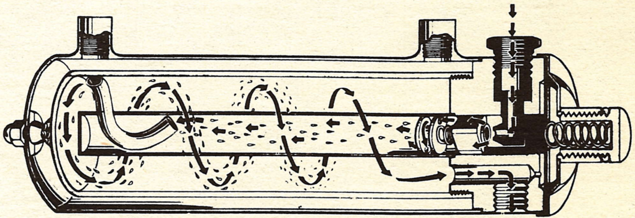

1-1/4 & 1-1/2" "XG"
5-A
5-B
5-C
5-D
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
R
S
GOVERNOR
POSITION OF LINE 'N' WHEN ENGINE IS EQUIPPED WITH A VACUUM GOVERNOR
• ECONOMIZER CONNECTION BELOW GOVERNOR WHEN VACUUM CONTROLLED GOVERNOR USED
VACUUM SPARK CONNECTION

26-30. Details of LPG carburetor produced by the Ensign Carburetor Co.

An easy starting feature on Ensign LPG carburetors provides a separate set of gas-air orifices which produce a more positive mixture for starting only. When choke plate (G) is closed, valve (H) will also close off the main passage (I). Air for starting is drawn through orifice (J) in disk (G) and gas for starting through a small orifice controlled by screw (K).

An economizer is provided on the Ensign LPG carburetor to provide two different mixtures in accordance with engine requirements. It provides the needed richer mixture for full throttle operation and a leaner economy mixture for part throttle operation. Details of the economizer are also shown in Fig. 26-30. Engine intake manifold is connected at (M) and the vacuum pulls back the diaphragm (O) against the pressure of the spring (Q). This closes off passage at (P). When the manifold vacuum reaches 4 to 6 inches of vacuum, the diaphragm is caused to move inward, opening the valve to a position shown by the dotted line. A fixed calibrated orifice (L) controls the flow of fuel through the economizer. Balance line connection (S) connects the vacuum existing in the carburetor air horn to the regulator and automatically balances the system for variation in the air cleaner and other air entrance losses.

Details of a vaporizer are shown in Fig. 26-31. In this unit, produced by the J & S Carburetor Company, the liquid flows into the vaporizer at the left end and is indicated by the arrows. When passing through the regulator the pressure of the liquid is reduced to approximately 7 lbs. This reduction in pressure results in part of the liquid being vaporized. The vapor and the balance of the liquid pass through the inner tube and are discharged from it at the right end. At this point, the mixture is given a whirling motion which keeps the liquid in contact with the walls of the vaporizing chamber, and is vaporized as it travels toward the outlet.



26-31. Details of the type J & S LPG vaporizer.

When the demand for gas by the engine is reduced, the balanced regulator which is placed between the vaporizer and the carburetor (on the J & S system) closes. The liquid butane-propane that is in the vaporizer and in contact with the heated wall of this chamber, will continue to build pressure. This pressure causes the liquid to be expelled from the vaporizing chamber into the inner chamber where it is out of contact with the hot walls of the vaporizing chamber. It is withdrawn as the engine continues to consume gas for idling.

QUIZ - FUEL SUPPLY SYSTEMS

1-On lawn mower engines, how is fuel usually supplied to the carburetor?

2-On modern passenger cars, what two methods are used to drive the fuel pumps?

3-For what purpose is the vacuum pump built into some types of fuel pumps?
   a. To operate the pistons in automatic chokes
   b. Operate windshield wipers
   c. Aid in pumping fuel

4-What is a major cause of excessive fuel pump pressure on a mechanical type fuel pump?
   a. Insufficient flexing of the diaphragm
   b. Clogged fuel cleaners
   c. Clogged line to the fuel supply tank

5-How much pressure should the conventional mechanical type fuel pump develop?
   a. 5 lb.
   b. 10 lb.
   c. 15 lb.

6-In 45 seconds how much fuel should be pumped by the average mechanical type fuel pump?
   a. 1 pint
   b. 2 pints
   c. 3 pints
   d. 32 ounces

7-What is the average vacuum developed by a vacuum pump that is built into a fuel pump?
   a. 5 in.
   b. 7-1/2 in.
   c. 10 in.
   d. 18 in.

8-What is a major advantage of using an externally mounted electrically operated fuel pump?

9-Name two main types of mechanically driven superchargers.

10-Which type of internal combustion engine will tend to detonate more?
   a. Supercharged
   b. Non-supercharged

11-What is a major advantage of the turbo-supercharger over the mechanically driven type?
   a. Little or no power required to drive it
   b. Develops more pressure

12-Name the two general types of fuel gauges.

13-Name two types of materials used in fuel filters.

14-Liquefied petroleum gas is a mixture of:
   a. Butane and propane
   b. Propane and heptane
   c. Methane and octane
   d. Butane and methane

15-Is the boiling point of propane higher or lower than zero degrees Fahrenheit.

16-Does LPG have a high or low octane rating?

17-Does LPG produce more or less carbon in an engine than gasoline?

FUEL INJECTION

DIESEL INJECTORS

As described in the unit on engine fundamentals, a Diesel engine compresses air, and at the point of maximum compression, fuel is injected into the combustion chamber. Ignition takes place as a result of the high temperature which has been created.

To force fuel into the combustion chamber of a Diesel engine requires a pump and an injector. Because of high pressures existing in the combustion chamber at the time of injection, the injection system must develop pressures well in excess of the combustion chamber pressure.

A Diesel fuel injection system in delivering the fuel to the combustion chamber must fulfill five main requirements:

1. Meter or measure the correct quantity of fuel injected.
2. Time the fuel injection.
3. Control the rate of fuel injection.
4. Atomize the fuel into fine particles.
5. Properly distribute the fuel in the combustion chamber.

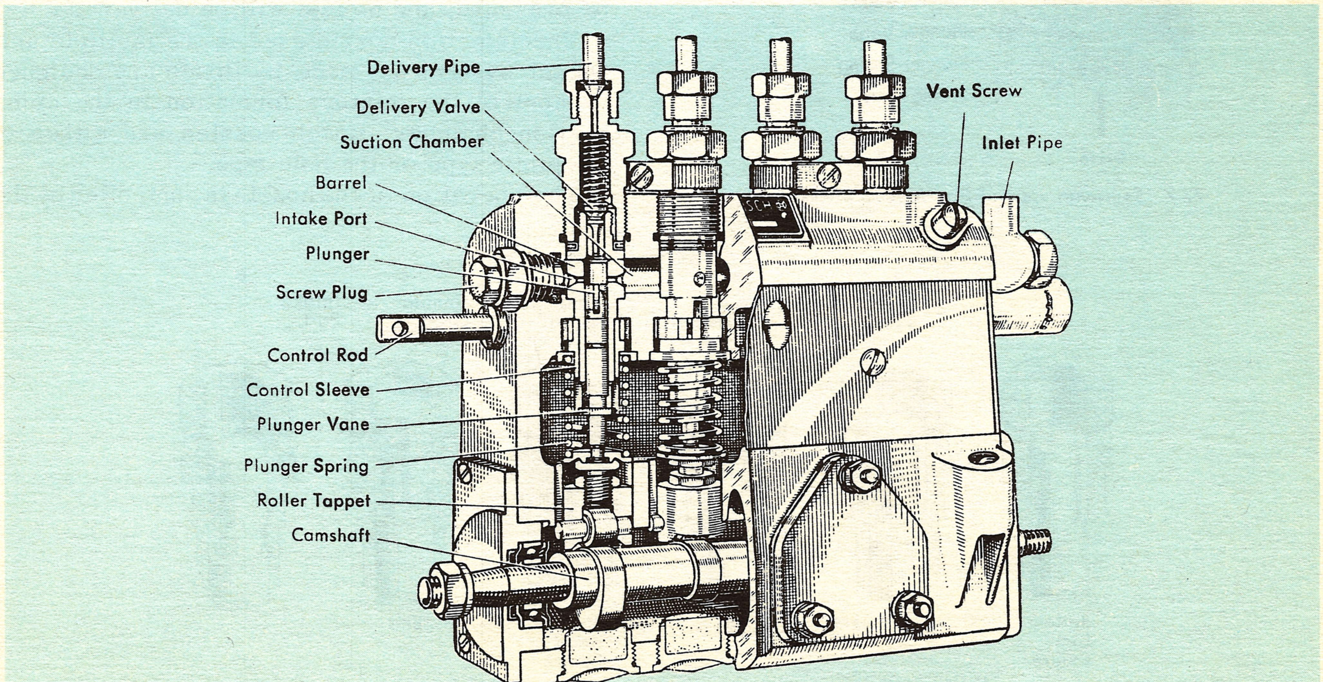
There are two different methods of fuel injection: air injection and mechanical or solid injection.

In the air injection system, a blast of air from an external source forces a measured amount of fuel into the cylinder.

In the solid injection system which is now used almost exclusively, fuel is forced into the cylinder by direct pressure on the fuel.

In the automotive field, there are four basic types of solid fuel injection systems:

1. Multiple unit type
2. Unit injection system
3. Distributor system


Delivery Pipe
Delivery Valve
Suction Chamber
Barrel
Intake Port
Plunger
Screw Plug
Control Rod
Control Sleeve
Plunger Vane
Plunger Spring
Roller Tappet
Camshaft
Vent Screw
Inlet Pipe

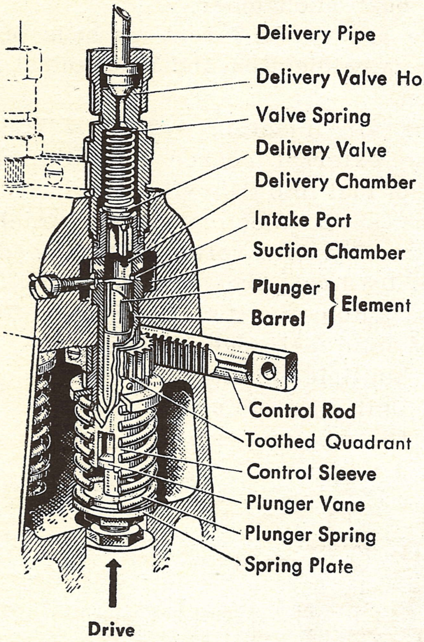
27-1. Bosch four-cylinder Diesel injection pump.

4. Pressure-time system

The multiple pump or unit fuel system includes in addition to the usual tank and cylinders, a low-pressure fuel transfer pump, a separate assembly mounted on the side of the engine containing an individual high pressure pump for each cylinder which meters and distributed pressurized fuel to the injectors, also an injector for each cylinder.

BOSCH DIESEL SYSTEM

The Bosch is a multiple pump type fuel system. Their injection pump for a four-cylinder engine is shown in Fig. 27-1. Each pump element is made up of a plunger and a barrel, Fig. 27-2.


Delivery Pipe
Delivery Valve Holder
Valve Spring
Delivery Valve
Delivery Chamber
Intake Port
Suction Chamber
Plunger
Barrel
Element
Control Rod
Toothed Quadrant
Control Sleeve
Plunger Vane
Plunger Spring
Spring Plate
Drive

27-2. Sectional view of Bosch pump element.

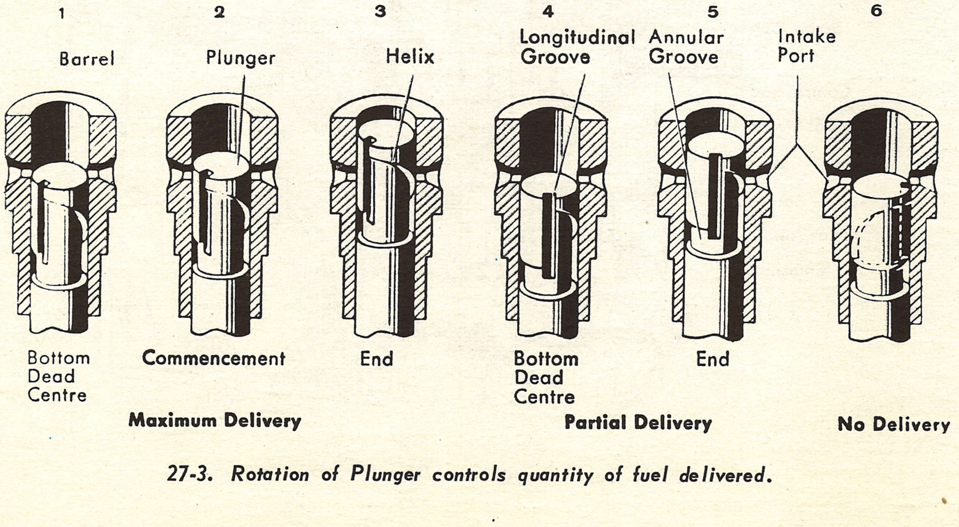
The plunger is so accurately fitted in the barrel that it will provide a seal without special packing even at high pressures and low speed. The plunger jacket is milled out along a helical line providing for the control helix on the plunger. The barrel has two opposing radial holes through which the fuel oil reaches the delivery chamber of the barrel, Fig. 27-2. In the compression stroke, the pump plunger is actuated by a cam; in the suction stroke, by the plunger spring. The valve is closed by a spring-loaded delivery valve connected with the delivery pipe to the respective nozzles in the cylinder. To vary the quantity of fuel delivered by the pump, the pump valve has a control sleeve on the upper end of which a toothed quadrant is clamped. A control rod meshes with the tooth quadrant so the pump plunger can be rotated during operation.

Various positions of the plunger are shown in Fig. 27-3.

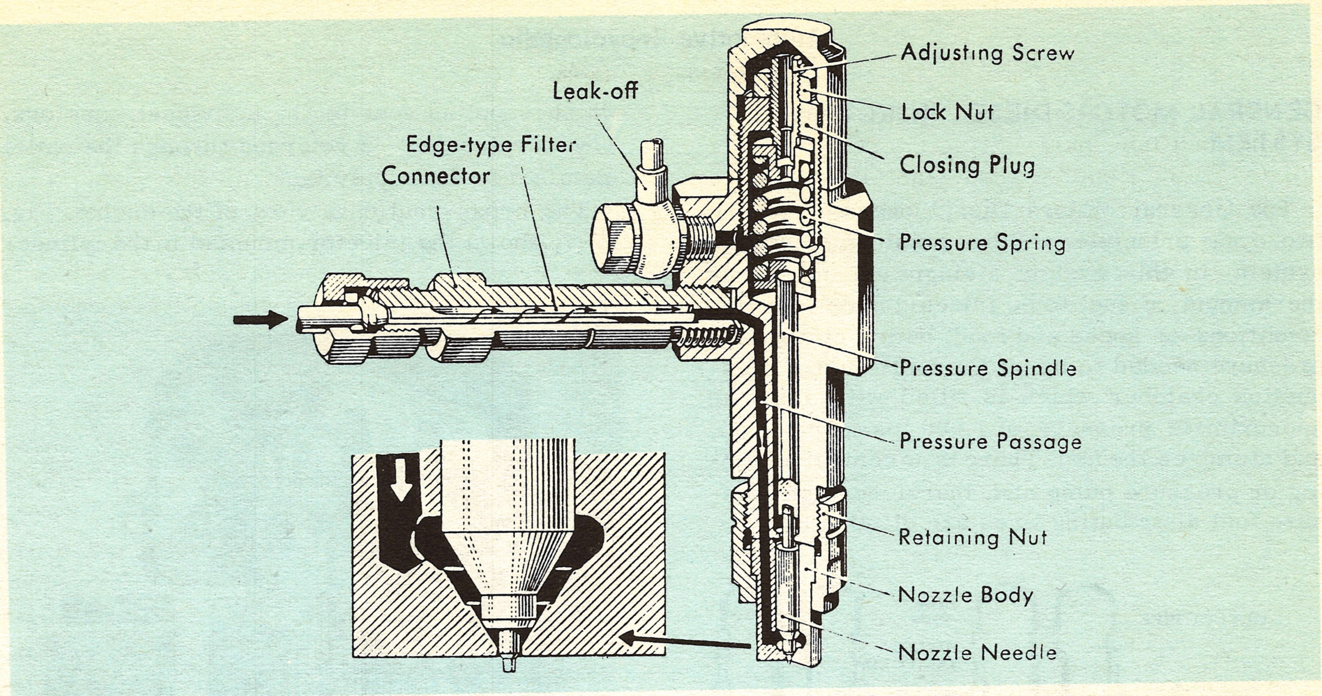
In its upward movement, the plunger closes the intake port, as shown at 2 and forces the fuel through the delivery valve to the delivery pipe. Delivery stops as soon as helix and inlet port coincide, as the delivery chamber of the barrel is from that moment connected to the suction chamber through the longitudinal and annular grooves. The fuel is thus forced back into the suction chamber. If the plunger is turned sufficiently far for the longitudinal groove and inlet port to meet, as shown at 6 (Fig. 27-3) the fuel in the delivery chamber is not subjected to pressure, and no fuel will be delivered.

The injection nozzle used in the multiple unit Diesel system as made by Bosch are designed to control the mixture formation in the combustion chamber. Bosch nozzles are either of the pintle type or the hole type.

The operation of the nozzle is controlled by the


1
2
3
4
5
6
Barrel
Plunger
Helix
Longitudinal Groove
Annular Groove
Intake Port
Bottom Dead Centre
Commencement
End
Bottom Dead Centre
End
Maximum Delivery
Partial Delivery
No Delivery

27-3. Rotation of Plunger controls quantity of fuel delivered.



Adjusting Screw
Lock Nut
Closing Plug
Pressure Spring
Pressure Spindle
Pressure Passage
Retaining Nut
Nozzle Body
Nozzle Needle
Leak-off
Edge-type Filter
Connector

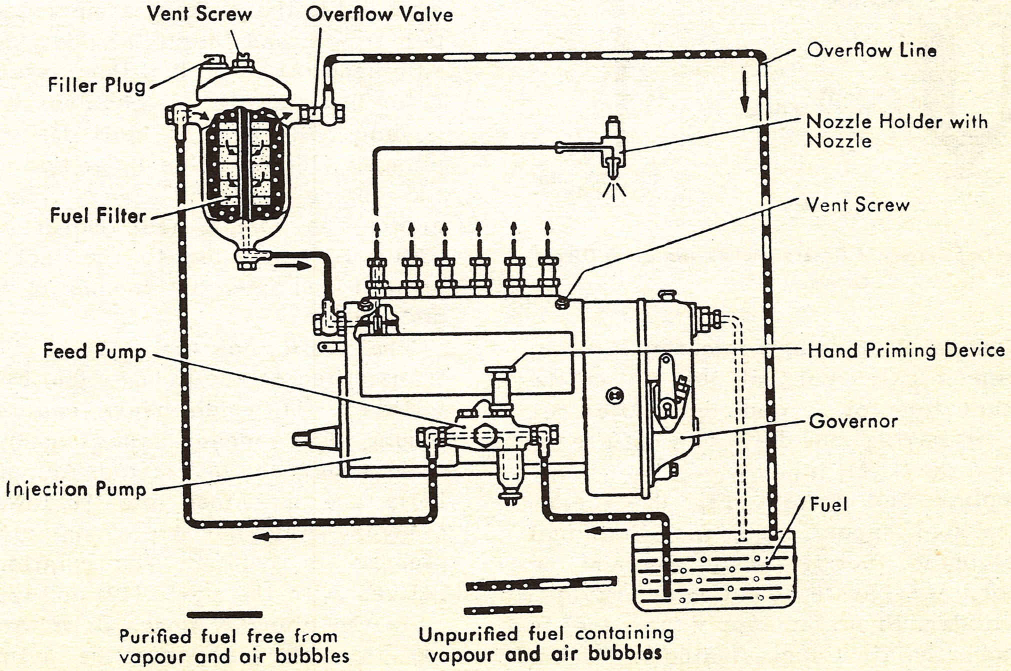
27-4. Details of Bosch nozzle holder with pintle type nozzle, (left).

fuel pressure. As soon as this pressure, during the delivery stroke of the injection pump, exceeds the tension of the pressure spring in the nozzle holder, the pressure acting on the pressure taper of the nozzle needle causes the latter to be lifted off its seat, and the fuel to be injected into the combustion chamber.

The nozzle opening pressure (which is adjustable) is determined by the initial tension of the pressure spring in the nozzle holder, Fig. 27-4. The needle stroke is limited by the plane surface on the nozzle holder.

When injected, the fuel takes the following path: Delivery pipe, through the connector and pressure passage of the nozzle holder, Fig. 27-4, then through groove and passage of nozzle, through injection hole or holes of nozzle and into combustion chamber of the engine.

A schematic view of a Bosch Diesel system is shown in Fig. 27-5.

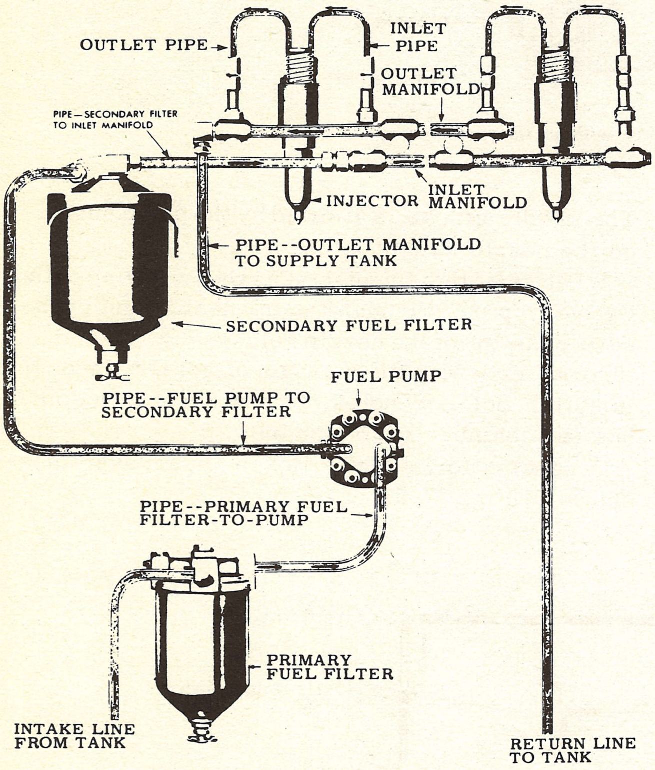


Vent Screw
Overflow Valve
Filler Plug
Overflow Line
Nozzle Holder with Nozzle
Vent Screw
Fuel Filter
Feed Pump
Hand Priming Device
Governor
Injection Pump
Fuel
Purified fuel free from vapour and air bubbles
Unpurified fuel containing vapour and air bubbles

27-5. Showing fuel circulation in Bosch system.

GENERAL MOTORS DIESEL INJECTION SYSTEM

The General Motors Diesel operates on the two-cycle principle, and has a unit injector fuel system. In this system a single unit measures the amount of fuel to be injected under varying conditions of speed and load, builds up the high pressure needed to inject the fuel into the combustion chamber which is filled with air at an approximate pressure of 1,000 lbs. per sq. in., and atomizes the fuel. There is no central metering or pressure pump and, therefore, high pressure fuel distributing lines are eliminated.

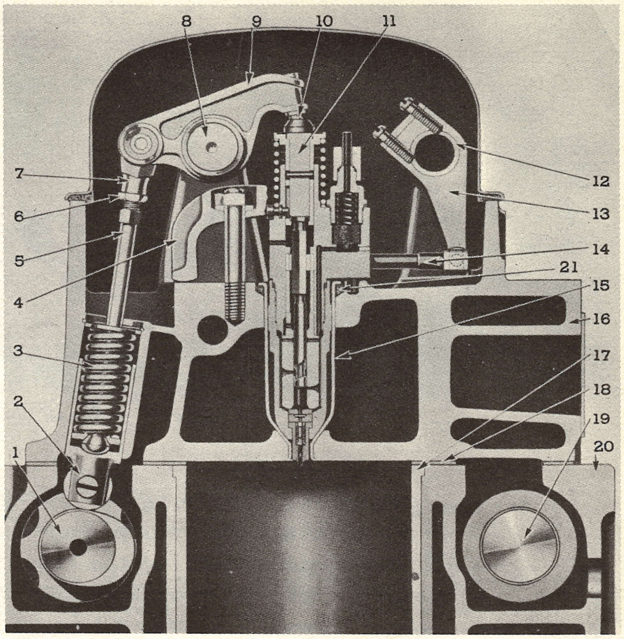

OUTLET PIPE
INLET PIPE
OUTLET MANIFOLD
PIPE—SECONDARY FILTER TO INLET MANIFOLD
INJECTOR
INLET MANIFOLD
PIPE--OUTLET MANIFOLD TO SUPPLY TANK
SECONDARY FUEL FILTER
FUEL PUMP
PIPE--FUEL PUMP TO SECONDARY FILTER
PIPE--PRIMARY FUEL FILTER-TO-PUMP
PRIMARY FUEL FILTER
INTAKE LINE FROM TANK
RETURN LINE TO TANK

27-6. Complete fuel system of General Motors two cycle Diesel engine.

In the General Motors unit injection system, high pressures exist only at the tip of the injector. Each injector is complete. After repair work, or having run dry, it is not necessary to prime the G. M. injector.

The complete fuel system, Fig. 27-6, consists of the fuel supply tank, fuel line, fuel filters, fuel pump, fuel line manifold, and the fuel injector. A separate injector is provided for each cylinder. From the supply tank, fuel is drawn through the first fuel strainer or filter by the fuel pump. The fuel is then forced through the second filter to the fuel intake manifold which supplies fuel to the individual injectors. The surplus fuel is returned through the outlet manifold to the supply tank.

The cross-sectional view of the engine, Fig. 27-7, shows the injector mounted in the cylinder head and Fig. 27-8 shows the details of the injector.

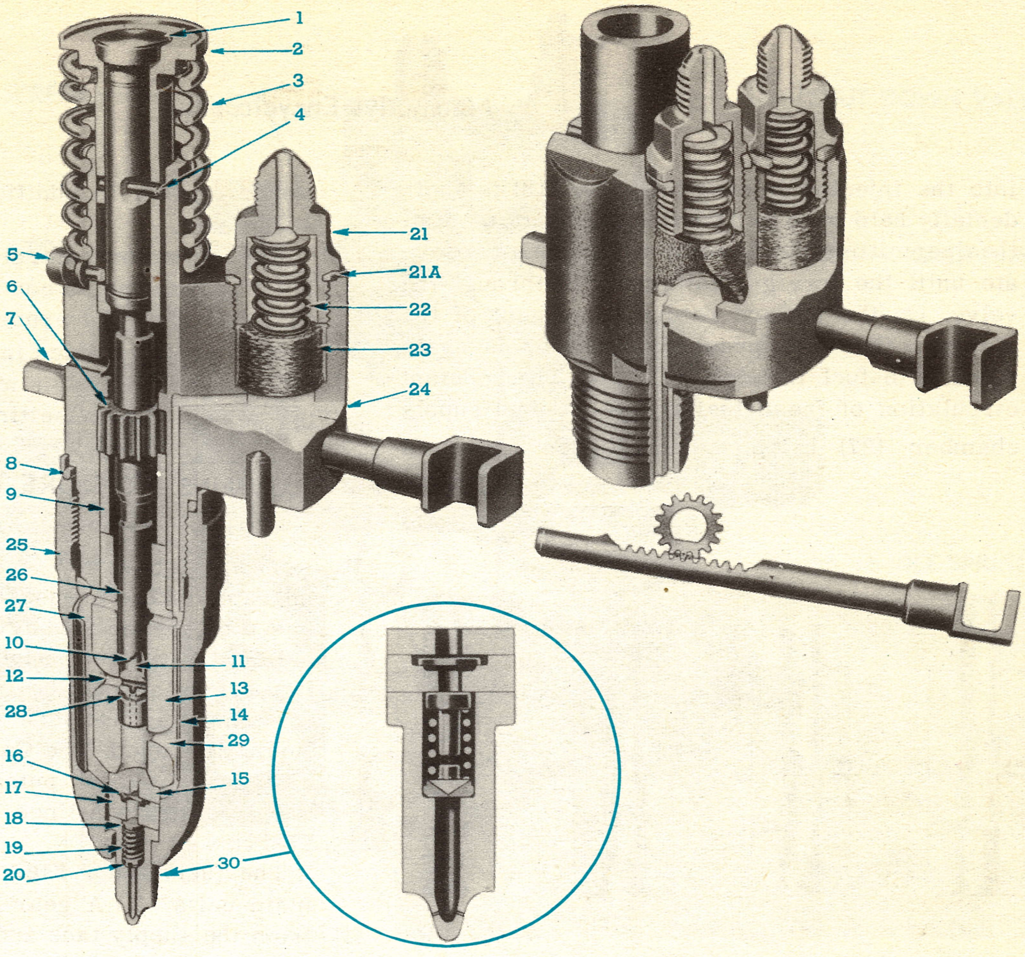

8
9
10
11
7
6
5
4
3
2
1
12
13
14
21
15
16
17
18
19
20

27-7. Cross section of General Motors Diesel Cylinder head and fuel injector.

In the G. M. unit injector, Fig. 27-8, fuel is supplied to the injector at approximately 20 lbs. per sq. in. and enters the body (24) through the filter cap (21). The fuel then passes through the filter (23) and fills the chamber (27) between the bushing (13) and the spill deflector (14). The plunger (26) operates up and down by means of the engine camshaft, push rods, and rocker arms. The plunger (26) operates in a bushing which is connected to the fuel supply in the annular chamber by means of the ports (12) and (29).

The motion of the injector rocker arm is transmitted to the plunger (26) by means of the follower (1) which bears against the return spring (3). By means of the gear (6), and rack (7), the plunger can be rotated. An upper and lower helix are machined into the lower end of the plunger for the purpose of metering fuel. As the plunger is rotated, the relation of the two helices with the ports (12) and (29) is changed.

As the plunger moves downward, the fuel in the injector high-pressure cylinder is first displaced through the ports (12) and (29), back into the supply chamber (27), until the lower



1. FOLLOWER.
2. FOLLOWER GUIDE.
3. PLUNGER SPRING.
4. FOLLOWER PIN.
5. STOP PIN.
6. GEAR.
7. RACK.
8. SEAL RING.
9. GEAR RETAINER.
10. UPPER HELIX.
11. METERING RECESS.
12. UPPER PORT.
13. BUSHING.
14. SPILL DEFLECTOR.
15. SPACER.
16. CHECK VALVE.
17. VALVE SEAT.
18. VALVE.
19. VALVE SPRING.
20. VALVE STOP.
21. FILTER CAP.

21A. GASKET-FILTER CAP.

22. FILTER SPRING.
23. FILTER ASSEMBLY.
24. INJECTOR BODY.
25. INJECTOR NUT.
26. INJECTOR PLUNGER.
27. FUEL CHAMBER.
28. LOWER HELIX.
29. LOWER PORT.
30. SPRAY TIP.

27-8. *Details of General Motors injector.*

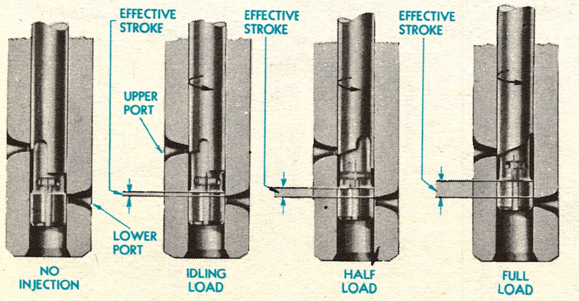
edge of the plunger closes the port (29). The remainder of the oil is then forced upward through the central passage in the plunger into the recess between the two helices. From there it can still flow back into the supply chamber until the upper helix closes the upper port (12).

At this point, both upper and lower ports are closed. The fuel remaining under the plunger is then forced through the spray tip and into the combustion chamber of the engine. Changing the position of the helices by rotating the plunger retards or advances the closing of the ports, and the beginning and ending of the injection period, at the same time controlling the desired amount of fuel which remains under the plunger for injection into the combustion chamber.

The various positions of the plunger from no injection to full injection are shown in Fig. 27-9. Full injection is obtained with the control rack pushed completely in. In that position the upper port is closed shortly after the lower port has been covered. In that way a full effective stroke and maximum injection is produced. When the control rack is pulled out completely, the upper port is not closed by the helix until after the lower port is uncovered. As a result, all of the fuel charge is forced back into the supply chamber and no injection of fuel occurs.

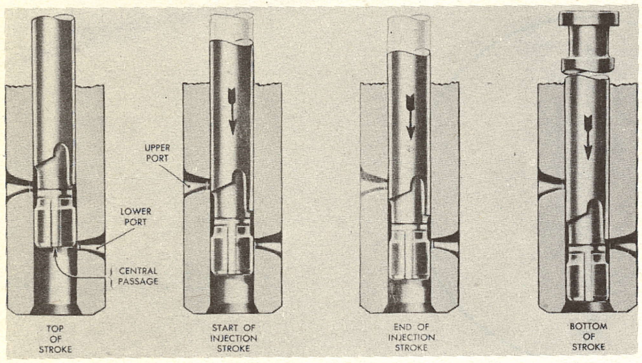
The four positions for the downward travel of the plunger are shown in Fig. 27-10. On the downward travel of the plunger, the metered amount of fuel is forced through the valve assembly, through the check valve (16), Fig. 27-8, and against the spray tip valve (18).

When sufficient pressure has been built up on the fuel, the spray tip valve is lifted from its seat and the fuel is forced through the small orifices in the spray tip (30) and into the combustion chamber. The check valve (16) prevents air leakage from the engine combustion chamber



27-9. *Four positions of the plunger from no injection to full injection of the General Motors injector.*

into the injector in case the valve (18) is accidentally held open by a particle of carbon or dirt, thus permitting the injector to continue to operate until the foreign matter works through the valve. On the upward return movement of the plunger, the high pressure cylinder is again filled with fuel through the ports. The constant circulation of fresh fuel oil in the fuel supply chamber (27) helps maintain even operating temperatures. In addition, all traces of air are eliminated.


UPPER PORT
LOWER PORT
CENTRAL PASSAGE
TOP OF STROKE
START OF INJECTION STROKE
END OF INJECTION STROKE
BOTTOM OF STROKE

27-10. Four positions for downward travel of the General Motors injector.

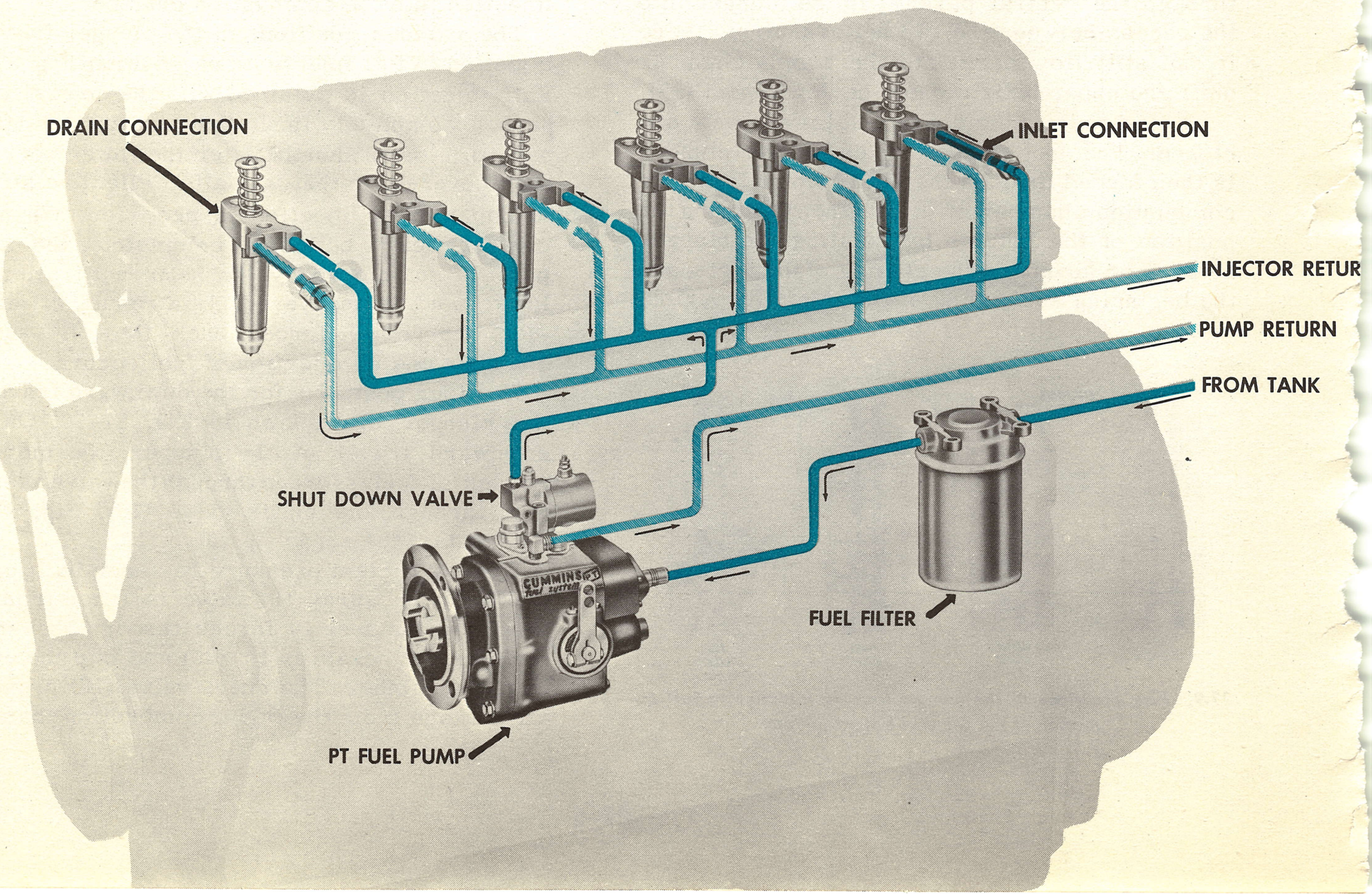
Each injector control rack is operated by a lever on a common control shaft. This, in turn, is linked to the governor and the throttle. These levers can be rotated independently on the control shaft by the adjustment of two screws which permit a uniform setting of the injector racks.

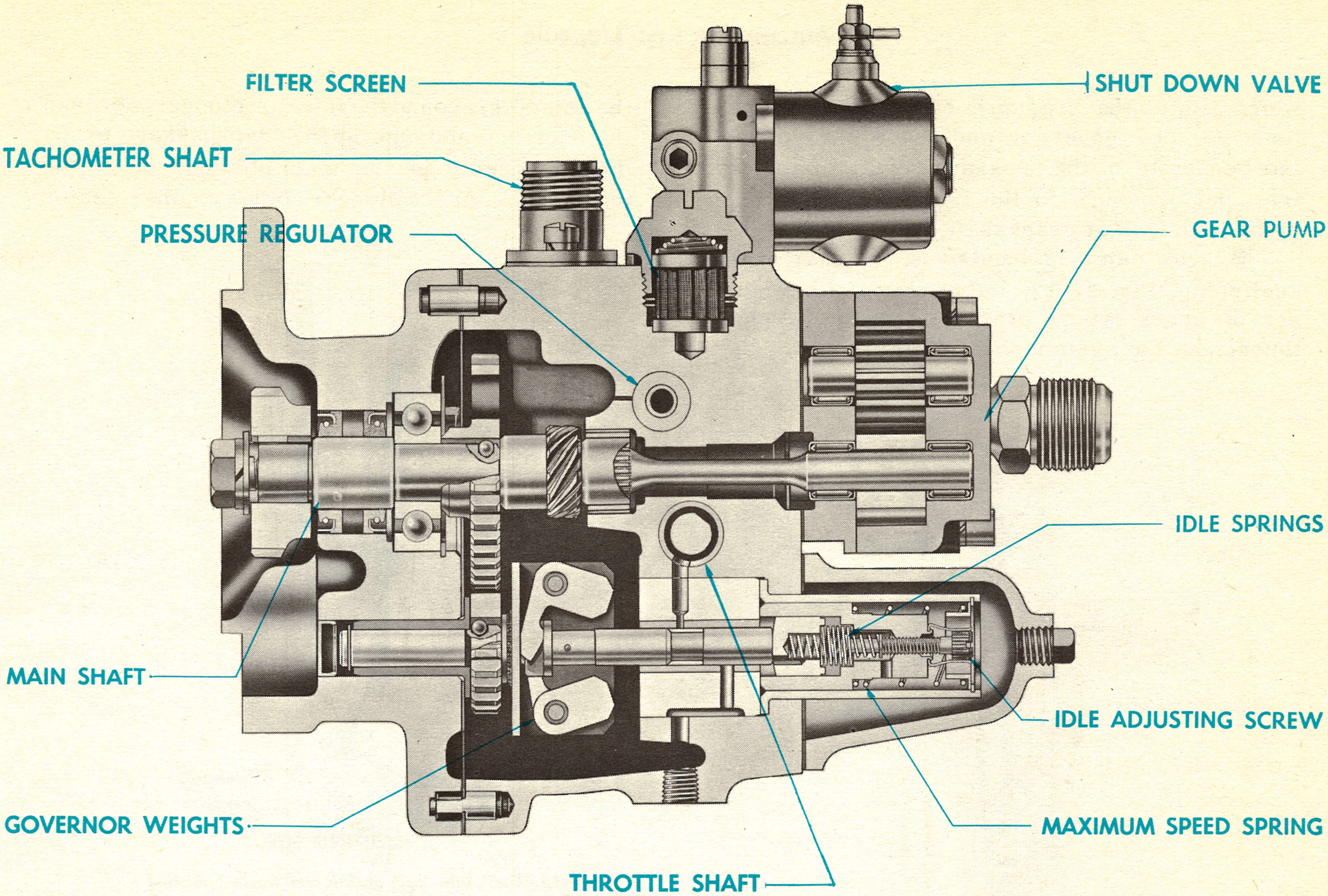
CUMMINS PRESSURE TIME SYSTEM

The Cummins PT system for Diesel engines operates on the pressure time principle which is based on the fact that by changing the pressure of a liquid flowing through a pipe, the amount of liquid coming out the open end is changed. Increasing the pressure increases the amount of liquid delivered. The Cummins PT system consists of the fuel pump (with governor), the supply and drain lines and the injectors, Fig. 27-11.

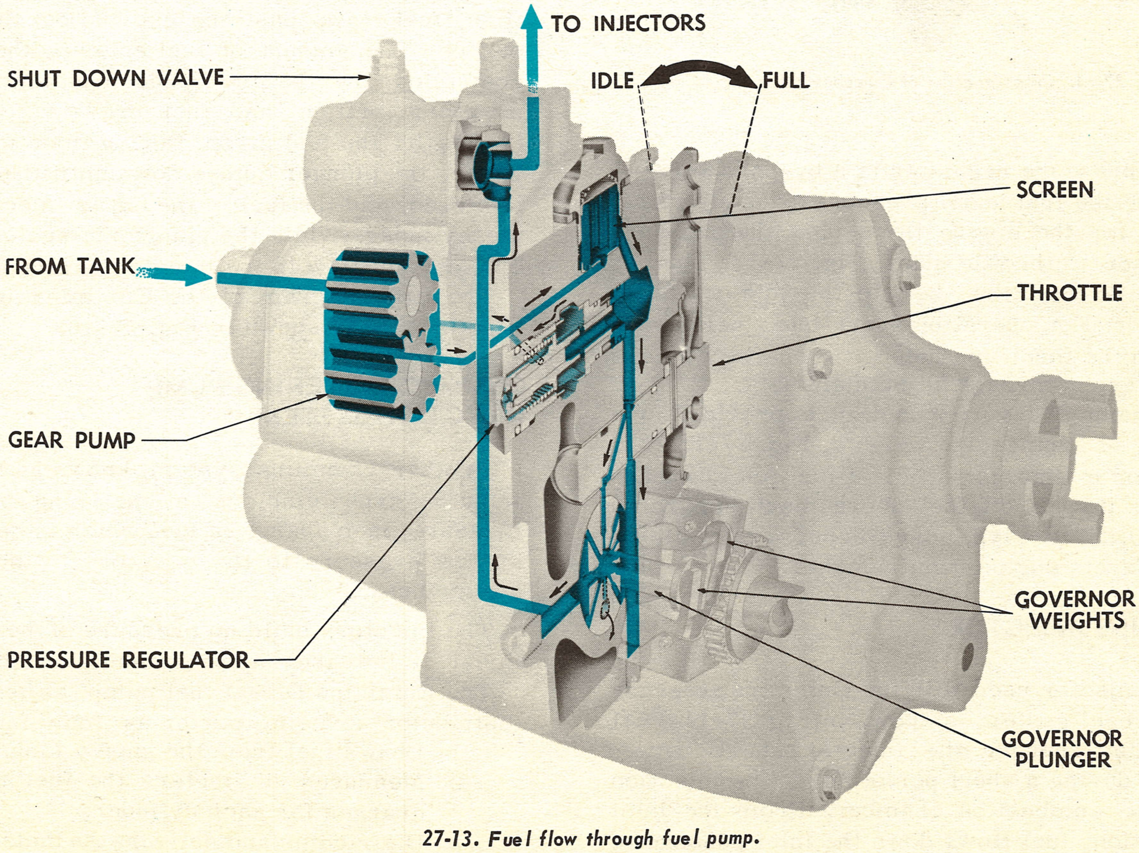
The fuel pump, Fig. 27-12, is made of three main units. (1) A gear pump, which draws fuel from the supply tank and delivers it under pressure through the pump and supply lines to the individual injector. (2) The pressure regulator

27-11. Fuel flow diagram of the Cummins pressure time system.


DRAIN CONNECTION
INLET CONNECTION
INJECTOR RETUR
PUMP RETURN
FROM TANK
SHUT DOWN VALVE
CUMMINS
FUEL FILTER
PT FUEL PUMP


FILTER SCREEN
SHUT DOWN VALVE
TACHOMETER SHAFT
PRESSURE REGULATOR
GEAR PUMP
IDLE SPRINGS
MAIN SHAFT
IDLE ADJUSTING SCREW
GOVERNOR WEIGHTS
MAXIMUM SPEED SPRING
THROTTLE SHAFT

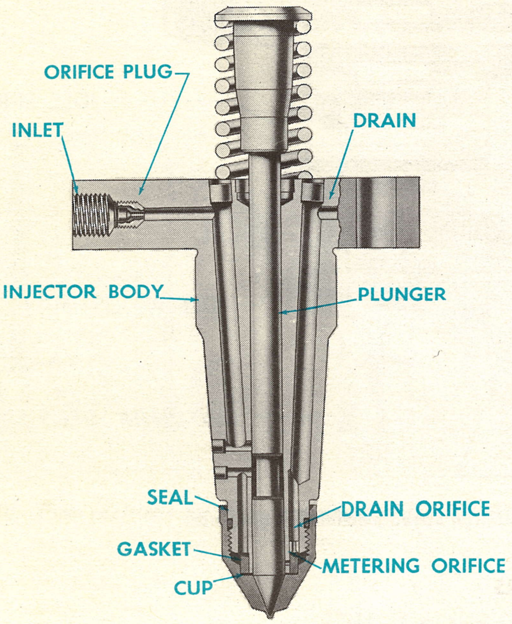
27-12. *Cross section of Cummins PT pump with idling and high speed mechanical governor.*


TO INJECTORS
SHUT DOWN VALVE
IDLE
FULL
SCREEN
FROM TANK
THROTTLE
GEAR PUMP
GOVERNOR WEIGHTS
PRESSURE REGULATOR
GOVERNOR PLUNGER

27-13. *Fuel flow through fuel pump.*

which limits the pressure of fuel to the injectors. (3) The governor and throttle which act independently of the pressure regulator to control fuel pressure to the regulators. The fuel pump is driven at crankshaft speed.

The gear pump is located at the rear of the fuel pump, Fig. 27-12, and consists of a single set of gears which pick-up and deliver fuel throughout the system, Fig. 27-11.



27-14. Cross section of Cummins injector.

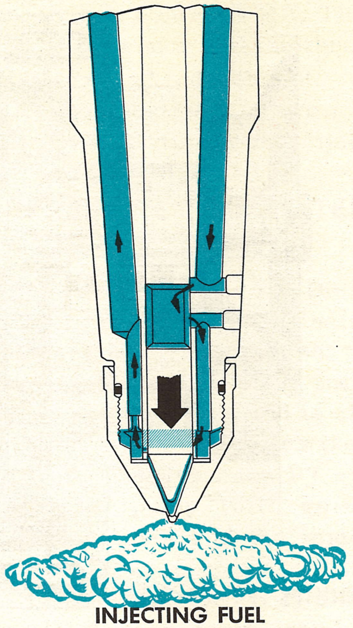
The pressure regulator is a by-pass valve to regulate the fuel under pressure to the injectors.

Fuel for the engine flows past the pressure regulator to throttle shaft, Fig. 27-13. The fuel passes around the shaft to the idle jet in the governor. For operation above idle, fuel passes through the throttling hole in the shaft and enters the governor through he primary jets.

Mechanical governor action is provided by a system of springs and weights, Fig. 27-13. The governor maintains sufficient fuel for idling and second; it cuts off fuel above maximum rated speed. Different types of governors are available for different engine requirements.

CUMMINS INJECTORS

The injector used with the Cummins pressure time Diesel system is shown in Fig. 27-14. Fuel circulates through the injector at all times, except during a short period following injection into the combustion chamber. From the inlet connection, fuel flows down the inlet passage of the injector, around the injector plunger, between the body end and cup, up the drain passage to the drain connections and manifold and back to the supply tank. As the plunger comes up, the injector feed passage is opened and fuel flows through the metering orifice into the cup. At the same time, fuel flows past the cup and out the drain orifice. The amount of fuel entering the cup is controlled by the fuel pressure against the metering orifice and fuel pressure is controlled by the fuel pump. During injection, Fig. 27-15, the plunger comes down until the orifice is closed, and the fuel in the cup is injected into the cylinder. While the plunger is seated in the cup, all fuel flow in the injector is stopped.



27-15. Fuel flow through injector while injecting fuel.

The flow diagram of the Cummins pressure time system is shown in Fig. 27-16.

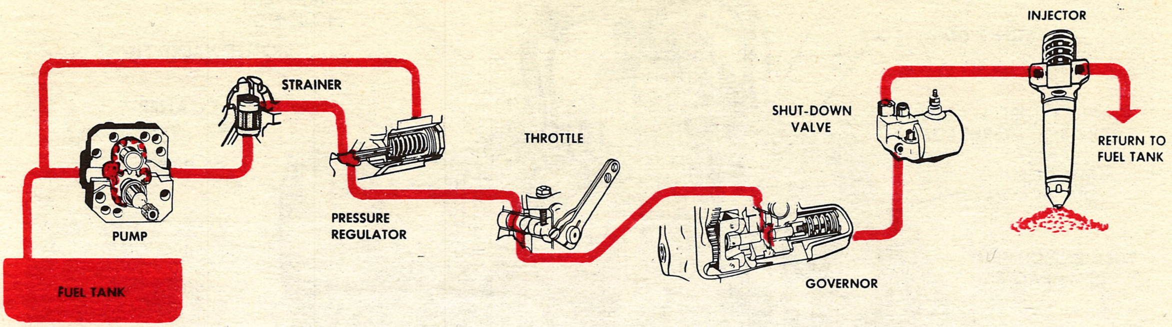
CUMMINS METERING PUMP INJECTION SYSTEM

Another Cummins system, known as the distributor type employs a metering pump to measure each charge of fuel which is delivered at low pressure to the injectors by means of a distributor.

The injectors build up pressure of the fuel and inject it into the engine combustion chamber.

The Cummins Diesel fuel pump, as used in the distributor system, performs four functions:

1. Draws fuel from the supply tank.
2. Measures or meters the fuel in equal charges for each cylinder.
3. Distributes and delivers the metered fuel



27-16. Pressure flow diagram of the Cummins pressure time system.

at the correct instant to the individual injectors in the engine.

4. Provides a governor for control of idling and maximum engine speeds.

The Cummins metering pump injection system (not illustrated) although still used on a number of installations, has been superseded by the Pressure Time System, described on preceding pages.

GASOLINE INJECTION

A system of gasoline injection is somewhat different from a Diesel injection system. The gasoline engine is also a good vacuum pump-which the Diesel engine is not--so it is customary to inject the gasoline into the inlet manifold near the inlet valve, and allow the cylinder vacuum to suck the fuel into the cylinder.

Because the gasoline is not thus injected into the cylinder against the compression pressure, as in a Diesel, the pump can use a lower pressure than the Diesel and is therefore known as a low pressure system.

The injection is of two types; the constant or "dribble" system where a very small stream of fuel runs constantly into the intake manifold while the engine is running, and the timed or intermittent system where a shot of fuel is supplied on the suction stroke of each cylinder.

The constant supply system does not need to be timed, but the intermittent system is timed with the crankshaft in the same manner as the ignition distributor

One of the first gasoline injection systems was developed by Robert Bosch in Germany for Mercedes racing cars and was an adaptation of the Bosch Diesel fuel pump previously described herein. The fuel was injected near the inlet valves and was timed.

A number of American racing cars use fuel injection of the constant type and find it satisfactory for racing purposes. Both the constant and intermittent types are used to some extent on American passenger cars.

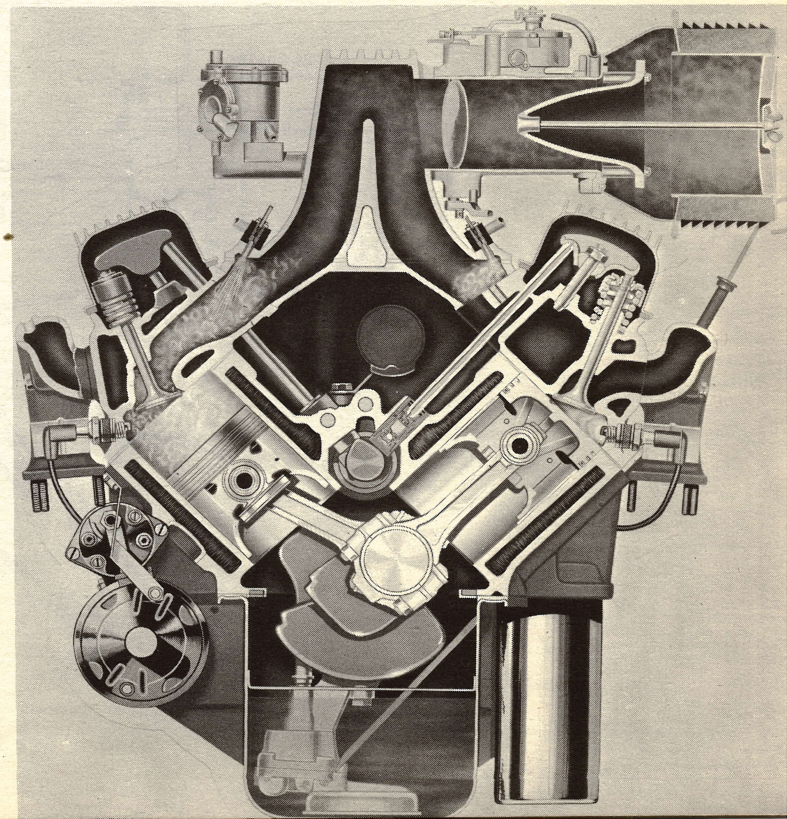
Among the advantages listed for fuel injection are:

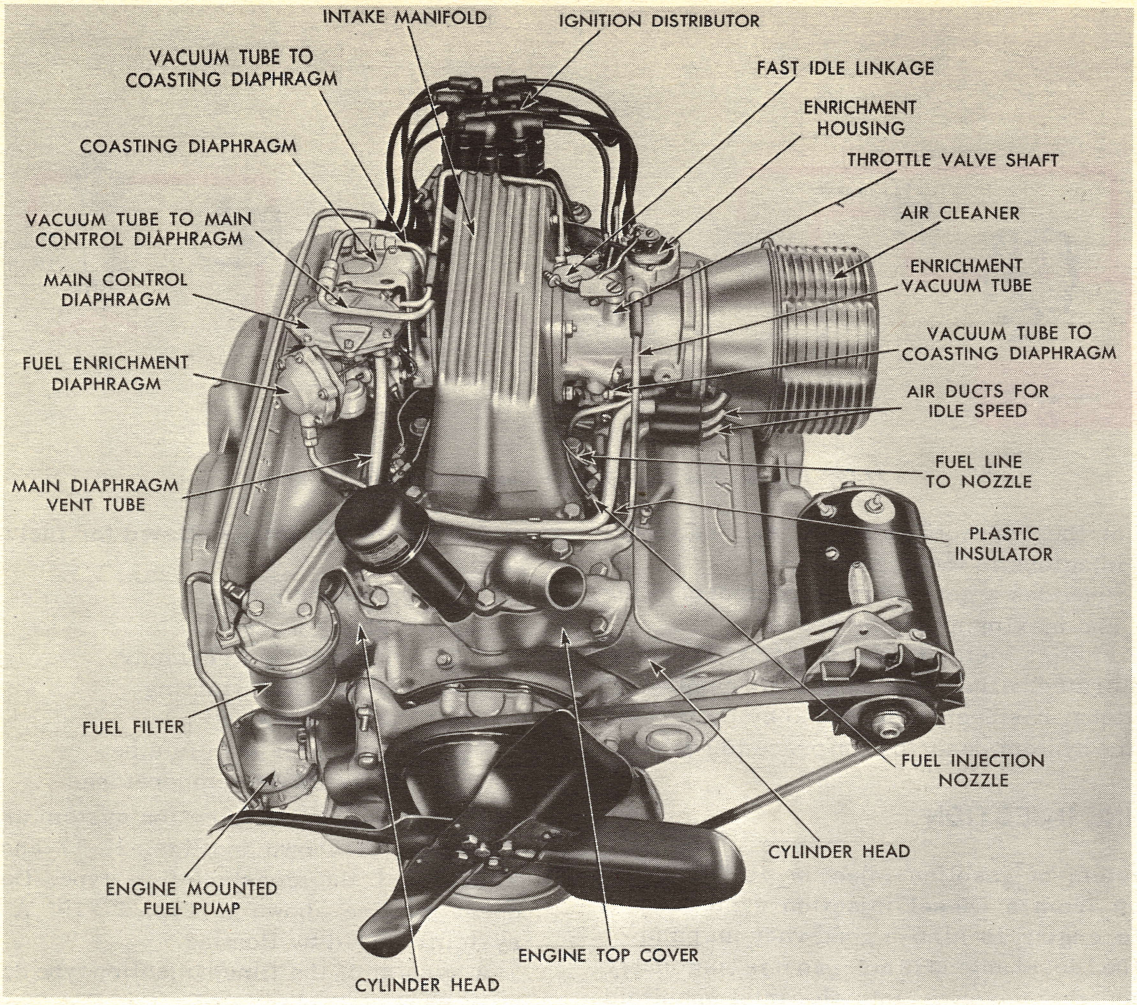
1. Increased power
2. Higher torque
3. Improved fuel economy
4. Quicker cold starting
5. Faster warm-up
6. No need for manifold heat
7. Lower intake temperatures

A typical gasoline injection system as used by Chevrolet is shown in Figs. 27-17 and 27-18. This is of the constant flow type. Details of operation are shown in Fig. 27-19. A similar system is used by Pontiac.

A system of the timed injection type developed by Marvel-Schebler is shown in Fig. 27-20. This uses a gear type belt drive. The operation of the system is shown in Fig. 27-21, and details of the injection pump is shown in Fig. 27-22.

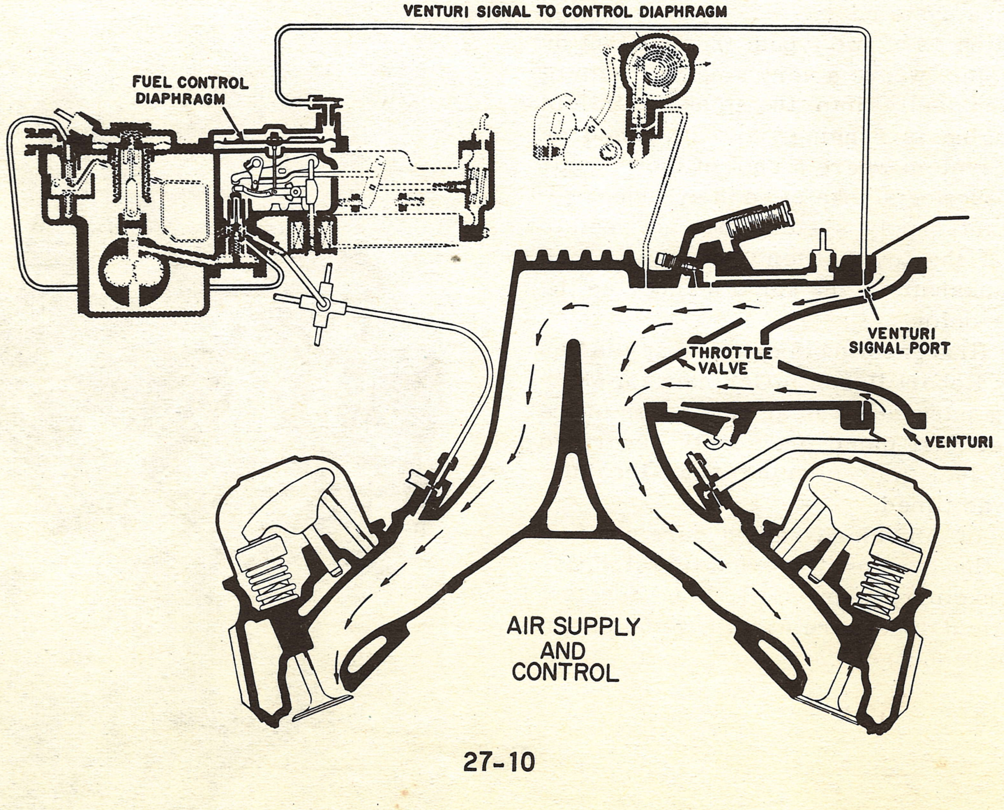
27-17. Fuel injection system installed on Chevrolet engine as optional equipment.



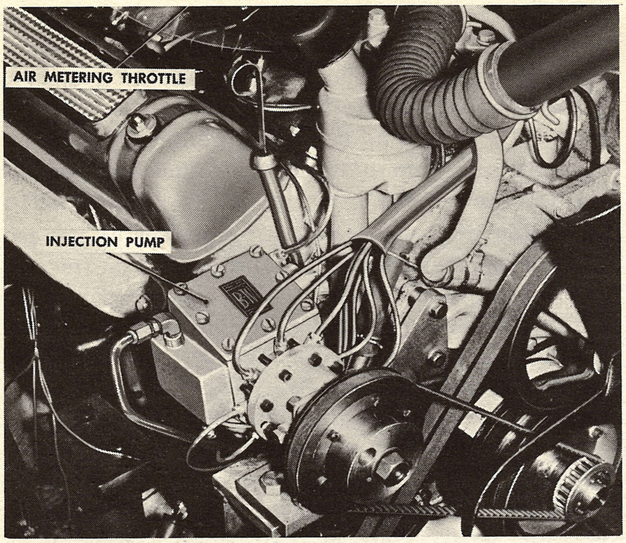

INTAKE MANIFOLD
IGNITION DISTRIBUTOR
VACUUM TUBE TO COASTING DIAPHRAGM
FAST IDLE LINKAGE
ENRICHMENT HOUSING
COASTING DIAPHRAGM
THROTTLE VALVE SHAFT
VACUUM TUBE TO MAIN CONTROL DIAPHRAGM
AIR CLEANER
MAIN CONTROL DIAPHRAGM
ENRICHMENT VACUUM TUBE
VACUUM TUBE TO COASTING DIAPHRAGM
FUEL ENRICHMENT DIAPHRAGM
AIR DUCTS FOR IDLE SPEED
FUEL LINE TO NOZZLE
MAIN DIAPHRAGM VENT TUBE
PLASTIC INSULATOR
FUEL FILTER
FUEL INJECTION NOZZLE
CYLINDER HEAD
ENGINE MOUNTED FUEL PUMP
ENGINE TOP COVER
CYLINDER HEAD

27-18. Fuel injection system installed on 1957 Chevrolet with parts identified.

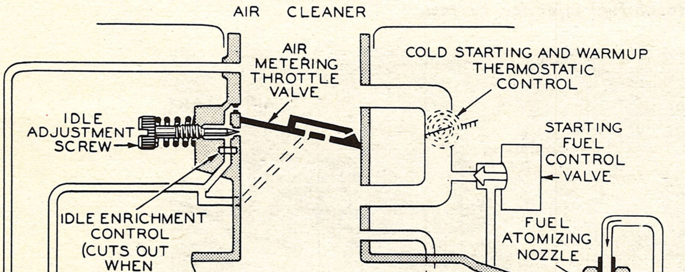
27-19. Schematic view of Chevrolet fuel injection system showing air flow and control system.


VENTURI SIGNAL TO CONTROL DIAPHRAGM
FUEL CONTROL DIAPHRAGM
VENTURI SIGNAL PORT
THROTTLE VALVE
VENTURI
AIR SUPPLY AND CONTROL

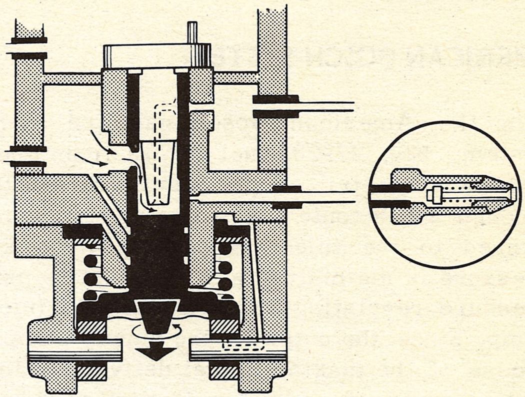
Another timed injection system is supplied by Bendix. This differs from other systems as it has an individual timed pump located near the intake valve of each cylinder. The individual pumps are operated by a solenoid magnet which is connected to an electronic controller or "brain" for timing purposes. This electronic control device regulates the time the injector opens and the duration of the opening. This is done by a number of sensors which determine


AIR METERING THROTTLE
INJECTION PUMP

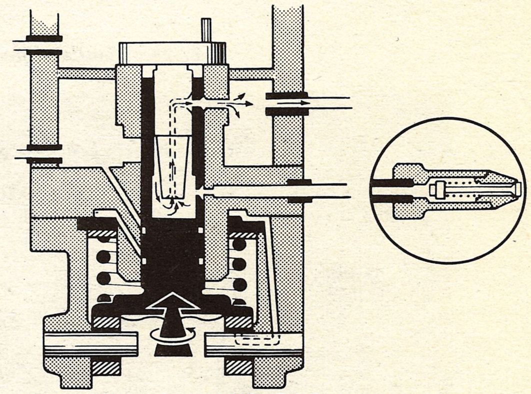
27-20. Installation of Marvel-Schebler fuel injection system on V-8 engine.


AIR CLEANER
AIR METERING THROTTLE VALVE
COLD STARTING AND WARMUP THERMOSTATIC CONTROL
IDLE ADJUSTMENT SCREW
STARTING FUEL CONTROL VALVE
IDLE ENRICHMENT CONTROL (CUTS OUT WHEN THROTTLE VALVE OPENS MORE THAN 4°)
FUEL ATOMIZING NOZZLE
INTAKE MANIFOLD
PUMP CONTROL HOUSING
LINE A
LINE B
PRESSURE EQUALIZING LINE
FUEL TANK
INJECTION PUMP
FILTER
FUEL SUPPLY PUMP
PUMPING AND DISTRIBUTING PLUNGER ASSEMBLY IN DISCHARGE PORTION OF STROKE

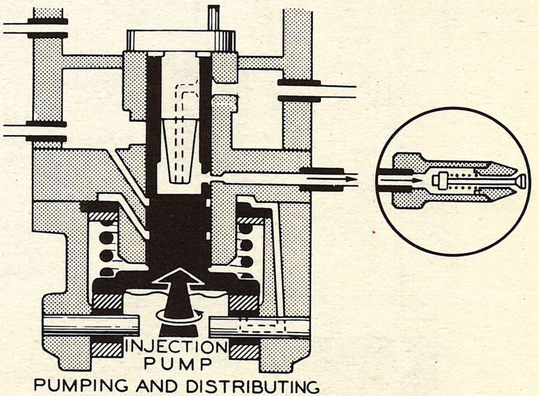
27-21. Schematic drawing of Marvel-Schebler fuel injection system.



PUMPING AND DISTRIBUTING PLUNGER ASSEMBLY IN INTAKE STROKE CYCLE



PUMPING AND DISTRIBUTING PLUNGER ASSEMBLY IN SPILL PORTION OF DISCHARGE STROKE CYCLE


INJECTION PUMP

PUMPING AND DISTRIBUTING PLUNGER ASSEMBLY IN DISCHARGE STROKE CYCLE

27-22. Schematic view of injector pumping cycles.

the conditions existing and regulate the fuel flow accordingly. One of the sensors is sensitive to the vacuum in the intake manifold, another is sensitive to the engine temperature, another is sensitive to the outside air temperature, a fourth records the throttle opening to enrich the mixture for acceleration and a fifth controls the idle mixture.

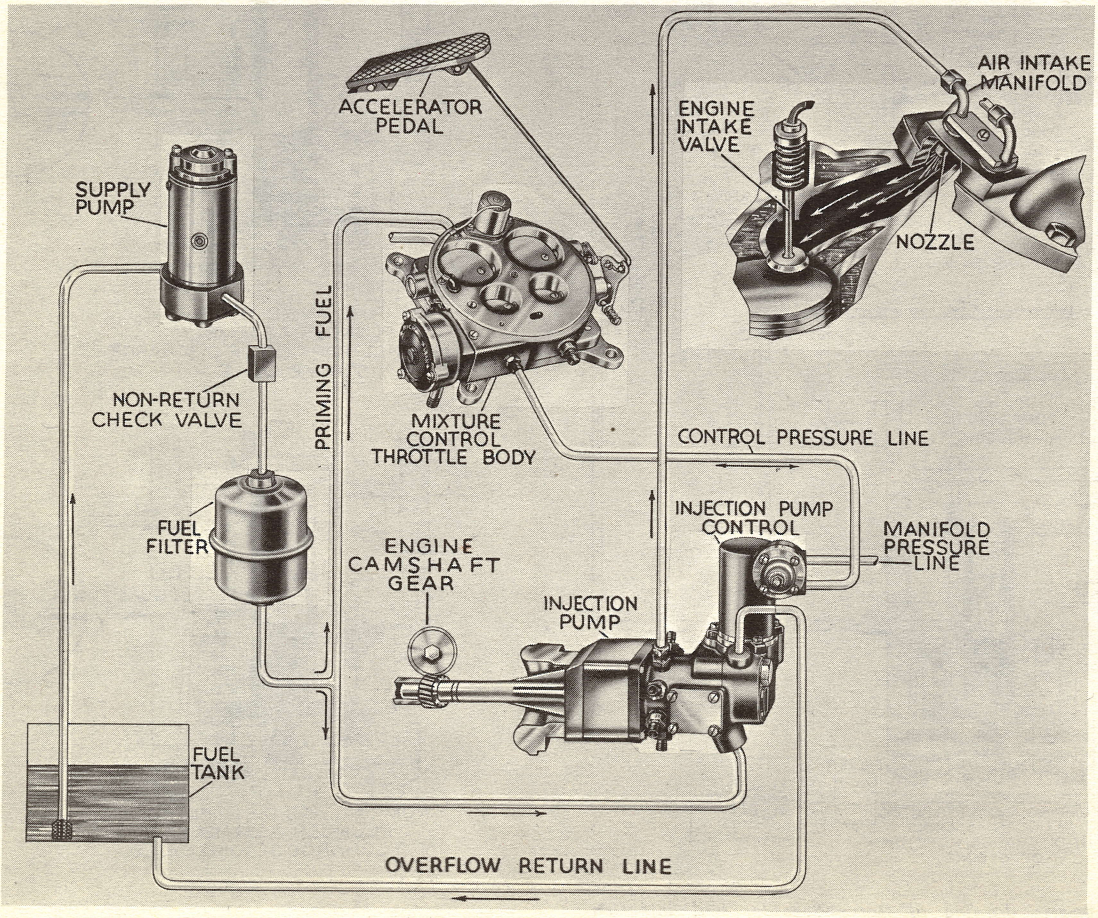
AMERICAN BOSCH SYSTEM

In the American Bosch gasoline injection system, Fig. 27-23, fuel drawn from the fuel tank by an electric supply pump is first filtered through a micronic fuel filter. Then, it is delivered to the injection pump, where supply pressure is maintained at a constant 20 psi by a pressure regulating valve built in the injection pump. Since the output of the supply pump is in excess of the maximum fuel delivery of the injection pump, the overflow fuel is piped back to the supply tank.

The injection pump, driven at half engine speed, meters and delivers fuel through eight outlets located on the pump periphery. Each of the pump outlets is connected to a nozzle which injects the fuel into the airstream, just before the intake valve at the beginning of the intake stroke. The end of the injection occurs before the closing of the intake valve, thus providing ample time for induction and thorough mixing of the fuel charge. The injection pump control, which is an air piston linked to the control shaft of the pump, receives control pressure from the mixture control unit, and adjusts the fuel delivery of the injection pump in relation to the engine load over the entire operating range.

The mixture control unit, mounted on the intake manifold in place of the carburetor, also contains the conventional throttle blades, the idle mixture adjustment screw and the idle speed adjustment screw. For cold weather operation, during engine warmup a modulating valve, operated by a temperature sensitive element, modifies the control pressure to produce a rich mixture. A solenoid actuated internal priming valve, fed at fuel supply pressure, provides excess fuel for cold starting.

27-23. Details of the American Bosch fuel injection system.


ACCELERATOR PEDAL
AIR INTAKE MANIFOLD
ENGINE INTAKE VALVE
NOZZLE
SUPPLY PUMP
PRIMING FUEL
NON-RETURN CHECK VALVE
MIXTURE CONTROL THROTTLE BODY
CONTROL PRESSURE LINE
FUEL FILTER
INJECTION PUMP CONTROL
MANIFOLD PRESSURE LINE
ENGINE CAMSHAFT GEAR
INJECTION PUMP
FUEL TANK
OVERFLOW RETURN LINE

QUIZ - FUEL INJECTION

1-On the compression stroke, what does a Diesel engine compress?
  a. Air
  b. Air-fuel mixture
  c. Diesel fuel

2-What are the four basic types of Diesel fuel injection used on automotive engines?

3-What five requirements must a Diesel fuel injection system fulfill?

4-In the Bosch system what does the rotation of the pump plunger control?
  a. The quantity of the fuel delivered
  b. Timing of injection
  c. Compression

5-What type engines are the General Motors Diesel?
  a. Four cycle
  b. Two cycle
  c. Sleeve valve

6-What type of injector system is used on the General Motors Diesel engine?

7-How many high pressure distributing lines are used on a four cylinder General Motors Diesel engine?
  a. Four
  b. Eight
  c. None

8-After repair work, or having run dry is it necessary to prime a General Motors Injector?

9-In the General Motors system, fuel is supplied to the injector at what pressure?
  a. 5 lb.
  b. 10 lb.
  c. 15 lb.
  d. 20 lb.

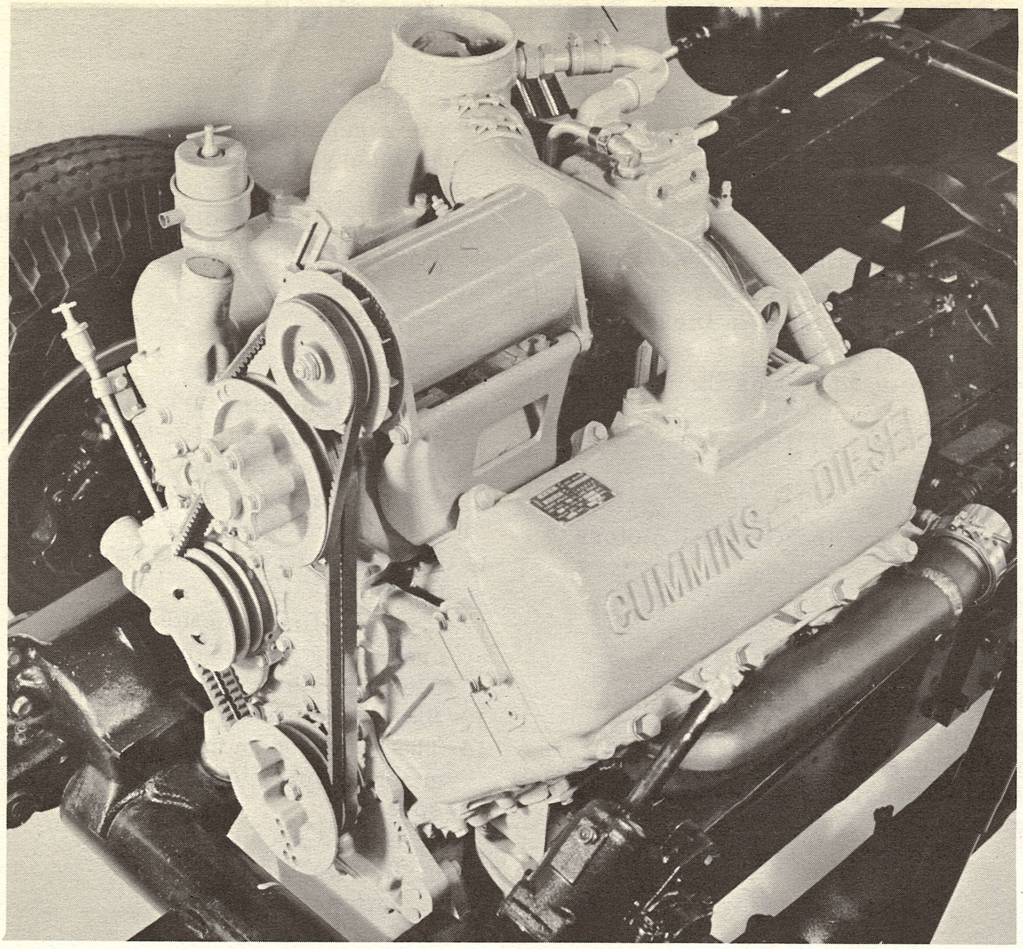
10-In the Cummins PT Diesel system what method is used to increase the flow of fuel?
  a. Increased pressure
  b. Increased size of jet
  c. Rotation of plunger

11-Does fuel flow all the time in the Cummins Injector?

12-In a gasoline injection system, the injection pressures are higher or lower than in a Diesel system?

13-Name two types of gasoline injection systems.

14-The injection pump on an American Bosch gasoline injection system is driven at what speed?
  a. Engine speed
  b. Half engine speed
  c. Twice engine speed


CUMMINS DIESEL

Left side view of Dodge-Cummins V6-200 diesel engine showing V-type design.

EXHAUST SYSTEMS

The exhaust system of an automotive engine consists of the exhaust manifold, exhaust pipe, muffler and tail pipe. See Figs. 28-1, and 28-2. It is designed to conduct the burned gases (or exhaust) from the engine, silence the noise of the exhaust, and conduct it to the rear of the vehicle.

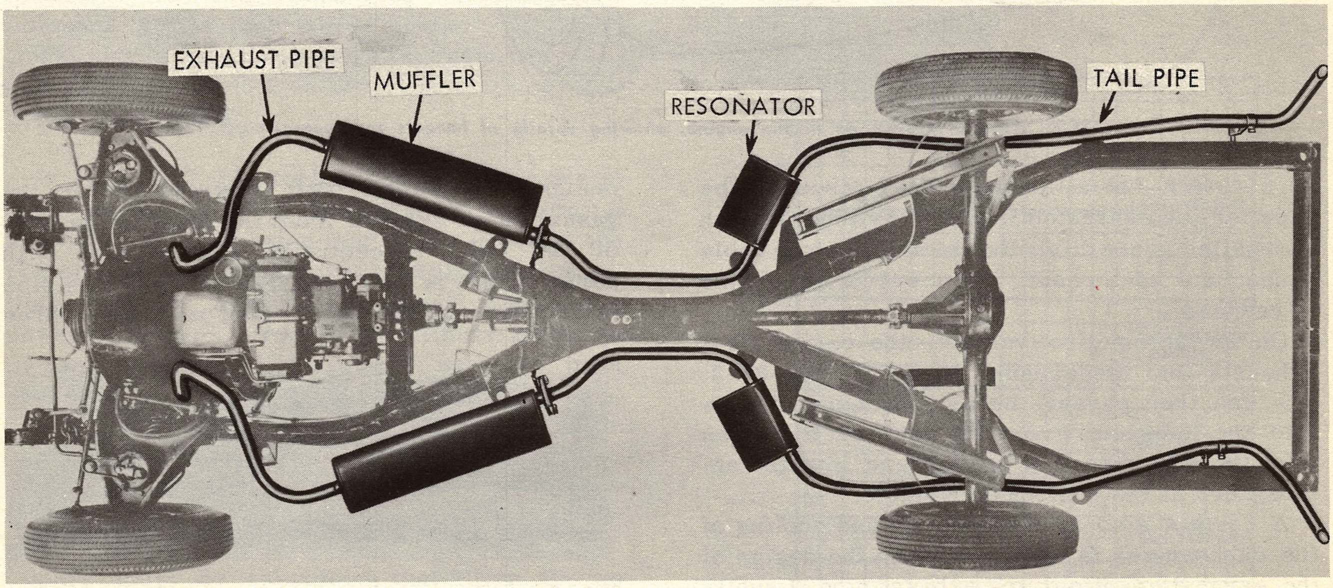
EXHAUST MANIFOLD

Exhaust manifolds are of many different types. On an in-line engine the manifold is usually bolted to the side of engine, Fig. 28-2, while on V-8 engines, separate manifolds are provided for each side of the "V." In such cases, a completely separate exhaust system may be provided for each side of the engine. Or, the two sides may be joined together by means of a "cross over pipe."

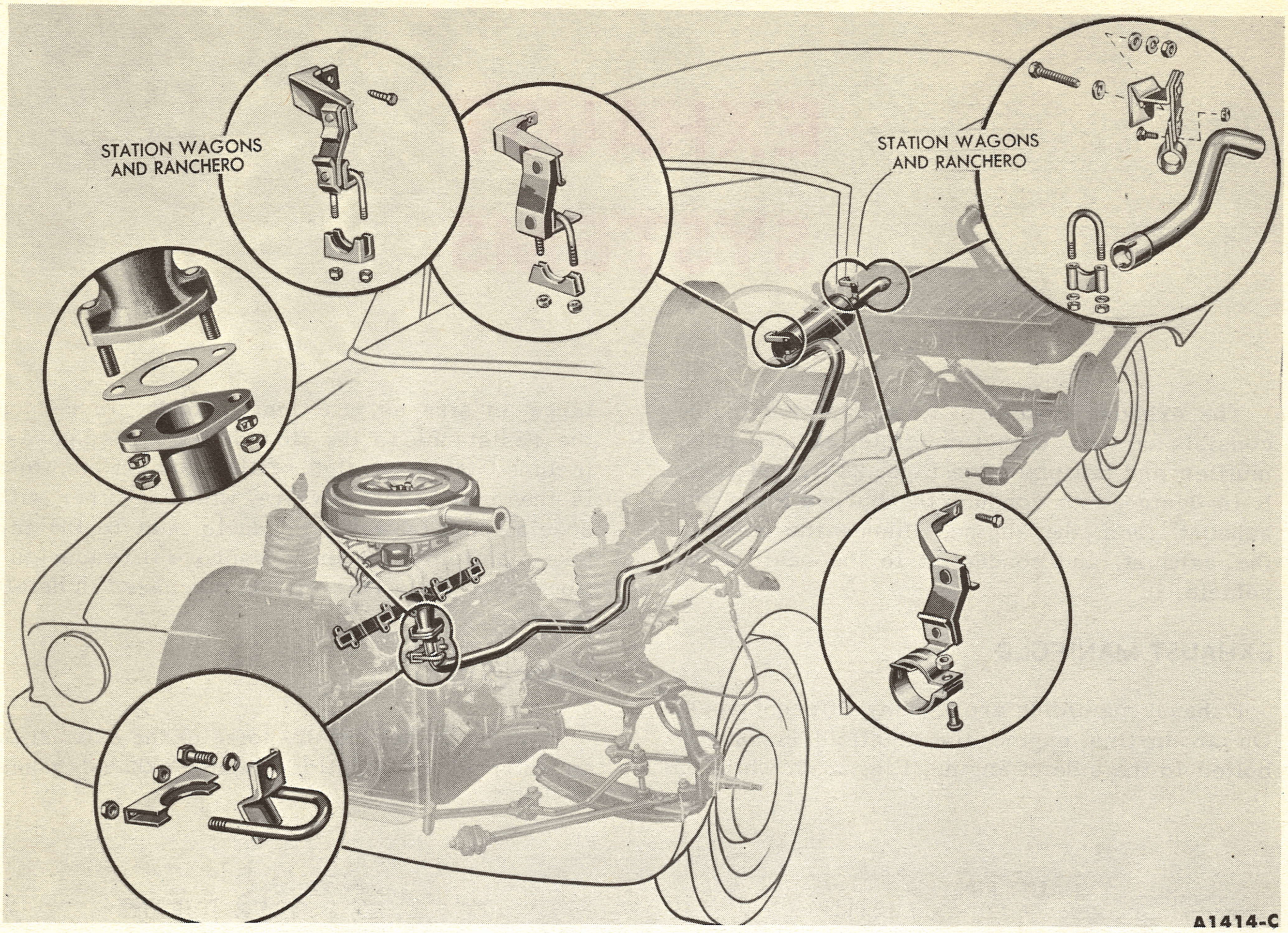
Regardless of the individual design, the passageways forming the manifold are made as large in size as practical in order to reduce the resistance to the flow of the burned gases. Included in the design of the exhaust manifold is the manifold heat valve, which together with special passageways, conducts heat to the intake manifold in order to improve the vaporization of the fuel. This will be discussed in detail later.

MUFFLERS

In order to reduce the noise of the exhaust of an internal combustion engine, exhaust gases from the engine are passed through a muffler, Fig. 28-3. The muffler is so designed that the gases are expanded slowly, and are also cooled before they are discharged into the tail pipe and the atmosphere. In addition, the design must be such that there is a minimum of back pressure developed. Back pressure prevents free flow of the exhaust gases from the engine, and



28-1. Dual exhaust system with resonators on V-8 engine.



28-2. Exhaust system on in-line engine, showing details of hangers and connections.

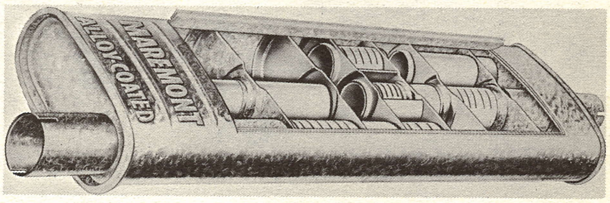
as a result, not all of the burned gases will be expelled, or exhausted from the cylinders. Such unexpelled gases dilute the incoming combustible gases, and as a result, the power of the engine is reduced.

On an automotive vehicle, the engine first exhausts into the exhaust manifold, Fig. 28-2. The gas then passes through the exhaust pipe into the muffler. From the muffler it passes into the tail pipe and from there into the atmosphere at the rear of the vehicle.

A certain amount of expansion and cooling of the exhaust gas is provided for in the design of the exhaust manifold and exhaust pipe. Usually these are designed to provide from two to four times the volume of a single cylinder of the engine. The additional expansion is then provided for in the muffler.

MUFFLER DESIGN

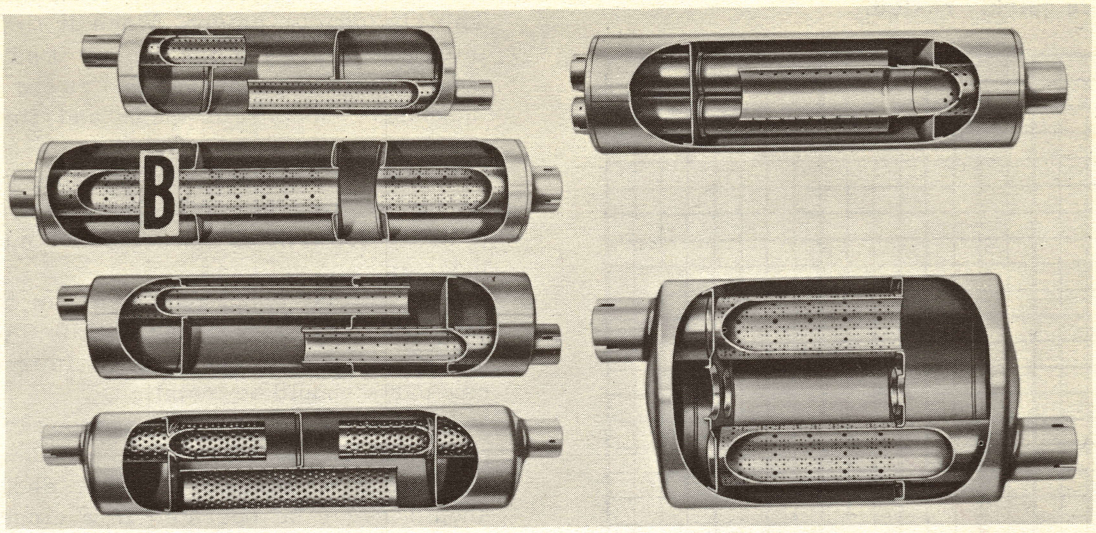
The design of the muffler varies with different manufacturers. One type is known as the straight through type, Fig. 28-4. In this design, a straight path is provided for the gases which extends from the front to the rear of the unit. A centrally located pipe with perforations is provided. Surrounding this pipe is a sheet metal shell, approximately three times the diameter of the pipe. In some instances, the space between the outer shell and inner pipe is open and in other cases it is filled with steel wool or some other heat-resistant sound deadener and porous material.



28-3. Special layers of aluminum, cadmium, lead and zinc alloys coatings are used to protect this muffler against corrosion.

Another type of muffler reverses the flow of the exhaust gases, Fig. 28-4, and has the advantage of conserving space. The double shell and two shell are still other forms of modern mufflers.

In order to reduce the noise of the exhaust below that attained by a single muffler, many systems are equipped with two mufflers in each line, Fig. 28-1. Such construction is particularly necessary on cars with a long wheel base and powered with a high output engine. The additional unit is usually known as a resonator.



28-4. *Different types of muffler construction. Muffler B is a straight through, while the others are variations of the reverse flow type of construction.*

BACK PRESSURE

In Fig. 28-5, the loss in engine power due to back pressure from the exhaust system is shown. It will be noted that as the speed of the vehicle increases, back pressure also increases. Note also for a given car speed, the loss in power increases very rapidly with the increase in back pressure. For example; with 2 lb. back pressure at 70 m.p.h., the power loss is 4 hp. and when the back pressure is 4 lb. the power loss has increased to 8 hp.

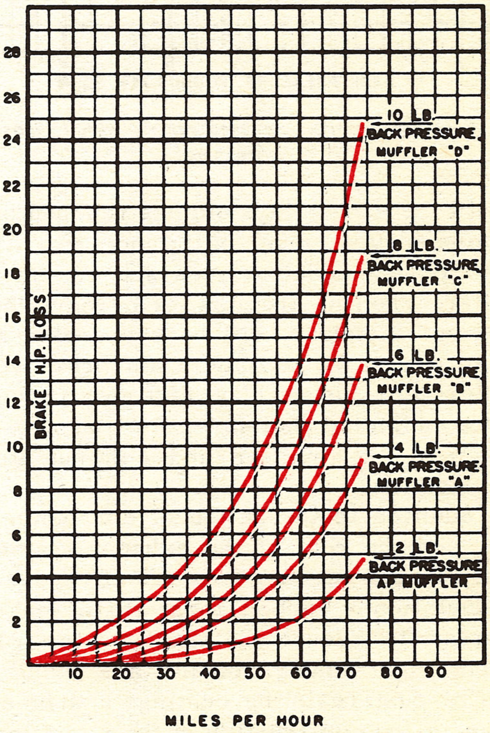
Similarly, fuel consumption is increased as muffler back pressure increases. This is shown graphically in Fig. 28-6.

Care must be exercised that there are no dents in the exhaust system that would tend to obstruct the free flow of the exhaust gases, as any obstruction would reduce power and fuel economy.

CORROSION OF EXHAUST SYSTEM

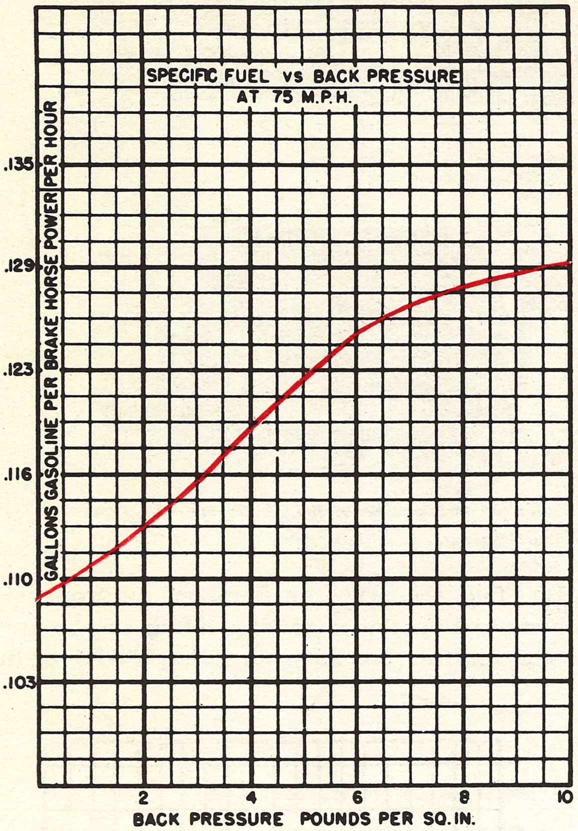
Mufflers, tail pipes and exhaust pipes wear out due to corrosion which occurs on both the inside and outside. The rusting that occurs on the outside is due to rain, snow and humidity. In some northern metropolitan sections this external rusting is accelerated by the use of salt on icy road surfaces.

By far the greatest amount of corrosion occurs inside the exhaust system particularly in the muffler, because for every gallon of fuel



28-5. *Showing the loss in horsepower due to exhaust back pressure.*

burned, approximately an equal quantity of water is formed. This water, produced by the combustion of the fuel, passes through the exhaust system. Mixed with acids also formed in the combustion process, the interior of the exhaust system is quickly rusted.



28-6. *Fuel consumption increases rapidly with increased back pressure.*

Until the exhaust system has reached operating temperature, much of the moisture will condense on the cool surfaces and collect in the muffler. Then as the muffler becomes hot, the collected moisture will be evaporated and be forced out of the tailpipe. On short drives, the muffler will not be hot enough to evaporate all the collected moisture. As a result, it will remain in the muffler and continue its corrosive action.

In addition to the action of corrosion, mufflers and the rest of the exhaust system will wear out and become less effective due to the accumulation of carbon, loose parts, leaks, etc. In order to reduce the tendency toward corrosion, most manufacturers are using some form of rust-resisting coatings and/or special alloys in the construction of their mufflers and pipes. In addition, stainless steel is also being used. Other manufacturers are using a ceramic coating on the interior of the mufflers and pipes.

EXHAUST GAS IS DEADLY

It is imperative that no leaks occur in the muffler and exhaust system, the reason being that exhaust gases contain carbon monixide. This is deadly poison. When it finds its way into the interior of the vehicle it causes headache, drowsiness, nausea and as the quantity is increased, unconsciousness and finally death results.

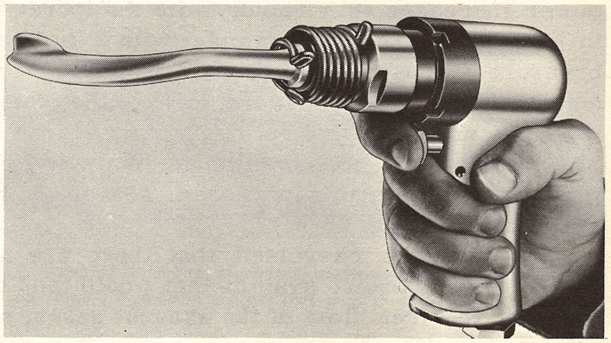
Surveys show that a 5 per cent of the cars on the road contain sufficient carbon monoxide to cause drowsiness and seriously impair driver judgment and reflexes.

Any exhaust leaks that occur in the exhaust system, from the exhaust manifold back to the tail pipe, should be repaired immediately or new parts should be installed.

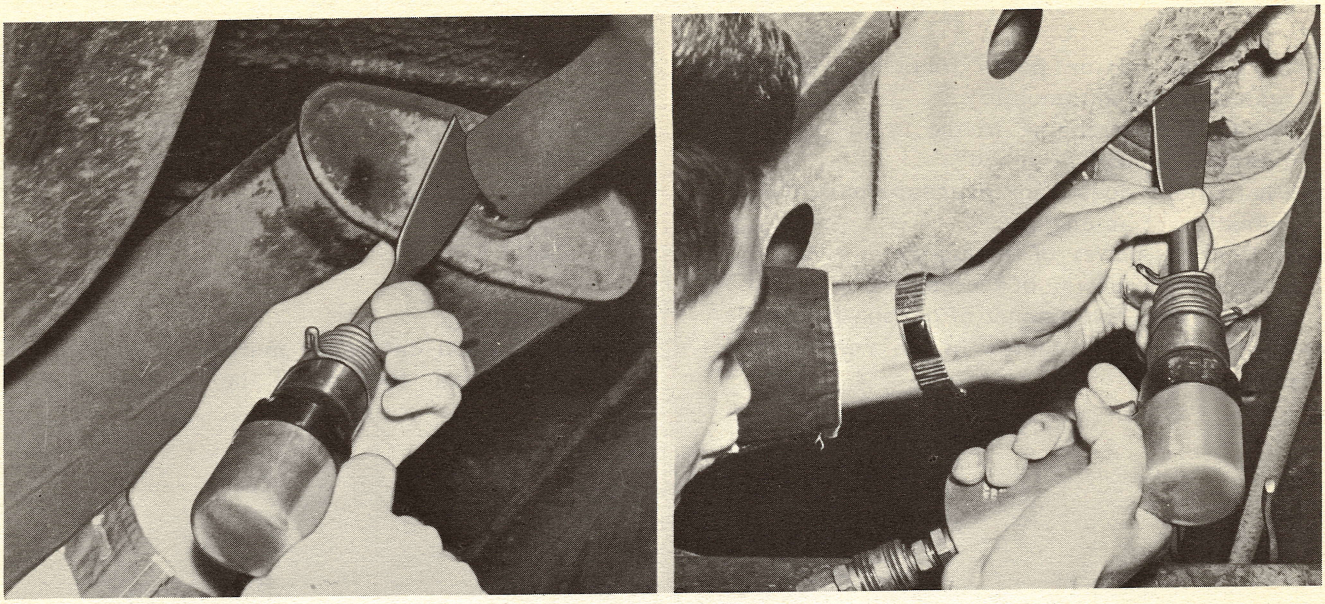
Just as exhaust gas is dangerous to the occupants of a vehicle, so is it dangerous to mechanics working in a repair shop. Engines should never be operated in a closed garage, unless adequate ventilation is provided. In large shops, special ventilating ducts are provided. These ducts are connected to the tailpipe of the engine so the exhaust is conducted outdoors.

SERVICING EXHAUST SYSTEMS

Because of the rusting that occurs in exhaust systems, it is frequently necessary to replace the various parts. The muffler and tail pipe are the parts replaced most frequently. Their life is largely dependent on the type of service in which the vehicle is used. If the car or truck is used mostly for short trips, it is not unusual for the tail pipe to require replacement in less than 10,000 miles. This is particularly true in the case of dual exhaust systems on V-8 engines. The reason is that as the exhaust is divided into two separate lines, they do not attain as high a temperature as would be the

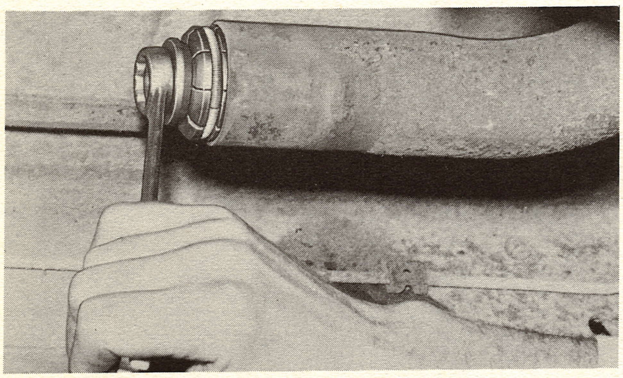


28-7. *One type of pneumatic muffler gun designed for muffler and pipe removal work.*



28-8. *Using a pneumatic muffler gun to cut through muffler pipes to speed removal.*

case in a single exhaust system. Operating at a lower temperature, less moisture is evaporated and consequently more rusting occurs.



28-9. *Special tool being used to expand end of pipe to facilitate installation of new muffler.*

As shown in Fig. 28-2, the exhaust system consists of the exhaust manifold, the exhaust pipe, the muffler and tail pipe. The joint between the manifold and the exhaust pipe is usually of the flange and gasket type. Brass nuts on steel bolts are usually used to hold the flanges together as the brass will not rust on the steel and is therefore more easily dismantled.

The usual construction of the exhaust pipe is to make the lower end slightly larger in diameter than the opening in the muffler. The muffler opening can then be slipped into the end of the exhaust pipe. A clamp is placed around the end of the exhaust pipe, and when tightened, the two parts are held securely together. The connection between the tail pipe and the muffler is of similar construction. Metal or combination metal and fabric straps, are used to hold the muffler and pipes securely in place.

To remove a muffler and tail pipe, the clamps and supporting straps are first removed. As the pipes usually have rusted to the muffler it is usually difficult to separate the joints. If any of the parts are to be used again, penetrating oil should be used liberally on the joints before attempting to pull them apart. In most cases, the parts are not to be used again and consequently they can be cut apart. Hacksaws can be used for that purpose, but power driven tools such as those shown in Fig. 28-7 and Fig. 28-8 will do the job much more quickly. To speed the job of installation, it is frequently necessary to expand the end of a pipe or muffler so that it can be more easily assembled. A special expanding tool is shown in Fig. 28-9.

QUIZ - EXHAUST SYSTEMS

1-What four major parts form the exhaust system on an automobile?

2-On an in-line engine where is the exhaust manifold usually attached?

3-What effect does back pressure have on the operation of an engine?
  a. Reduces power of the engine
  b. Increases power of the engine
  c. Increases the amount of carbon monoxide

4-What is a major factor in the rusting of a muffler?
  a. Short distance driving
  b. Long distance driving
  c. High speed

5-What material is used in making the nuts used to bolt together the flange between the manifold and exhaust pipe?
  a. Cast iron
  b. Steel
  c. Castellated
  d. Brass

6-The forward end of the muffler is larger or smaller than the end of the exhaust pipe?

FUNDAMENTALS OF ELECTRICITY, MAGNETISM

ELECTRICITY

Not only does the ignition system of the automobile depend on electricity for its operation, but many other parts do also. For example, starting and lighting require electricity as does the horn, turn signals, control units on the automatic transmission and overdrive units, fuel gauges, cigarette lighters, radio and many other accessories. Equally important, much of the testing equipment used in adjusting and testing the starting, lighting and ignition systems is electrical.

A thorough knowledge of the fundamentals of electricity is therefore necessary to the automotive mechanic who wishes to be successful in the maintenance, repair and troubleshooting on modern automotive vehicles.

STATIC ELECTRICITY

Rubbing a piece of amber with a piece of silk will cause the amber to attract bits of paper, straw, dried leaves and other light dry material. The same effect can be produced by rubbing a rod of glass or hard rubber with a handkerchief. In fact many other non-metallic materials are found to have this property which is known as static electricity.

It has also been found that when a rod of hard rubber was rubbed with a piece of fur and then held close to a pith ball suspended on a thread, the pith ball would be attracted to the rod. Buf if allowed to touch it, the ball would spring away. Then if a glass rod, rubbed with a piece of silk is held close to that same pith ball, it would attract the ball, but after contact was made it would be repelled as it previously had been by the hard rubber rod.

Further experiments show that all electrified materials behave either as glass or rubber. Glass is said to have a positive charge and hard rubber a negative charge. It was also discovered that two strips of hard rubber electrified by rubbing with fur would repel each other. Two glass rods behaved in a similar manner. However, when an electrified rod of rubber was suspended near an electrified rod of glass, they would attract each other.

ATTRACTION AND REPULSION

From that simple experiment came one of the most important laws of electricity: Similarly electrified bodies repel each other, while oppositely electrified bodies attract each other. This same law which applies to magnets will be discussed later.

WHAT IS ELECTRICITY?

In spite of the fact that electricity has been in use for many years, no one can explain just what electricity is. Through the course of years, many different theories have been advanced as to the nature of electricity. Today, the electron theory is generally accepted.

ELECTRON THEORY OF ELECTRICITY

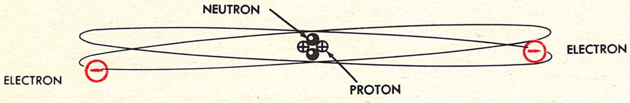
It has been generally established that all matter (the earth, rocks, minerals, chemicals, elements, etc.) consist of tiny particles called molecules. These molecules, in turn are made of two or more smaller particles called atoms. These atoms are further divided into even smaller particles which are called protons, neutrons and electrons.

These particles (protons, neutrons and electrons) are the same in all matter, regardless of whether it is a gas, a liquid or a solid. The different properties or characteristics of the matter result from the arrangement and number of protons, neutrons and electrons which form the atoms of which matter consists.

The proton has a natural positive charge of electricity. The electron has a negative charge, while the neutron has no charge at all but adds weight to the matter.

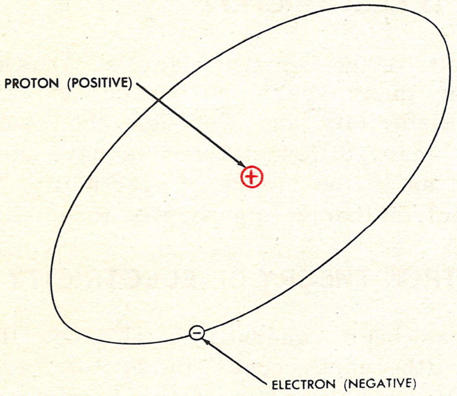
CENTRAL CORE OF ATOM

Protons and neutrons form the central core of the atoms about which the electrons rotate, much as the earth and other planets rotate about the sun, Fig. 30-1. Electrons carry the smallest negative charge of electricity which neutralizes the positive charge of the protons.



30-1. The electrons rotate about the central core consisting of protons and neutrons, much as the earth and other planets rotate about the sun.

The simplest atom of all is the hydrogen atom which consists of one positively charged proton and one negatively charged electron, Fig. 30-2. Copper is a more complicated atom. As shown in Fig. 30-3, it has 29 electrons circling about its nucleus of protons and neutrons in four different orbits. The electron is not held very strongly to the nucleus, and as a result it can become a free electron.



30-2. The hydrogen atom is the simplest atom and consists of one positively charged proton and one negatively charged electron.

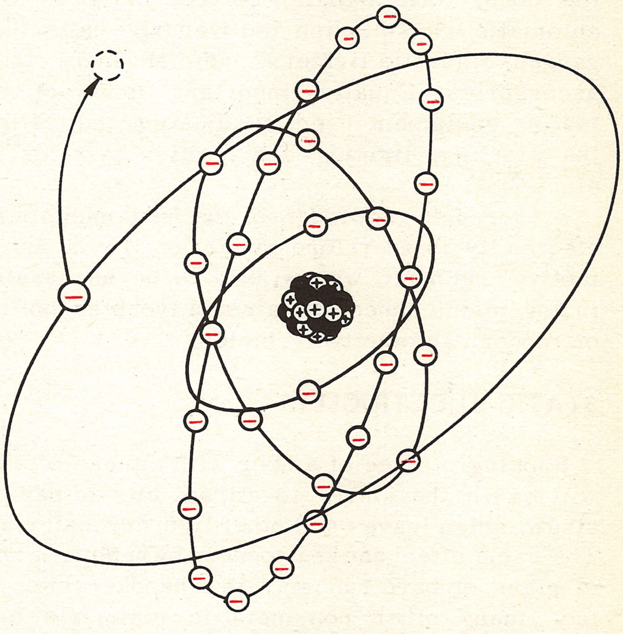
SIZE OF ATOM

It is difficult to conceive the size of the atom. The mass of the electron is about .000,000,000,000,000,000,000,000,000,911 of a gram. Assuming the size of a proton in an hydrogen atom is the size of a baseball and located in Kansas City, then the orbit of the electron would reach from the Atlantic coast to the Pacific. In spite of the size, the small proton would weigh 1838 times as much as the electron.

From the foregoing, it can be understood that in spite of the extremely small size of the electrons and protons, they are separated by relatively vast distances. An appreciation of this distance between the proton and electron is necessary to understand the flow of electricity.

INSULATORS

The hydrogen atom, as previously described is the simplest atom. Other atoms such as those forming copper, iron or silicon are much more complicated. The nucleus in most elements is composed of protons and neutrons which are surrounded by closely held electrons which never leave the atom. These are called bound electrons. When this type of electron predominates in an element or compounded material, the material is an insulator or a nonconductor of electricity.



30-3. Copper consists of 29 electrons circling about its nucleus in four different orbits. The nucleus consists of both neutrons and protons.

CONDUCTORS

In other types of material, the nucleus is surrounded by another group of electrons which can be made to move from one atom to the other when electricity is applied. Fig. 30-3. Electrons of this type are known as free electrons and the materials are called conductors of electricity.

SPEED OF ELECTRICITY

The speed of electricity is 186,000 miles per second. However, that does not mean that the electrons travel from one end of the circuit to the other at that speed. Actually, the forward movement of the electrons is no more than a drift. Free electrons, available as the result of overlapping electron orbits in conducting materials, are pulled from one atom to another, and temporarily rotate about each new center.

ELECTRON DRIFT

The rate at which the free electrons drift from atom to atom determines the amount of current flow. In order to create a drift of electrons through a circuit, it is necessary to have an electrical pressure, which is called voltage.

In other words, electric current is a flow of electrons, and the more electrons in motion, the stronger the current. The greater the concentration of electrons at a battery or generator terminal, the higher the pressure between the electrons. The greater this pressure is, the greater the flow of electrons.

VOLTS -- AMPERES -- OHMS

The pressure between the electrons is measured in volts, while the flow of electrons is measured in amperes.

Opposing the flow of electrons is the resistance of the conductors. As pointed out previously, some materials offer greater resistance than others; iron more than copper; copper more than silver. Also a conductor of small diameter will offer greater resistance to the flow of electrons than will conductors of large diameter. Such resistance is measured in ohms.

OHM'S LAW

There is a definite relation between the voltage, the resistance and the current flowing in an electrical circuit. This relationship is known as Ohm's law which states that the voltage impressed on a circuit is equal to the product of the current in amperes and the resistance in ohms. When given in a mathematical formula it is written:

$$E = IR$$

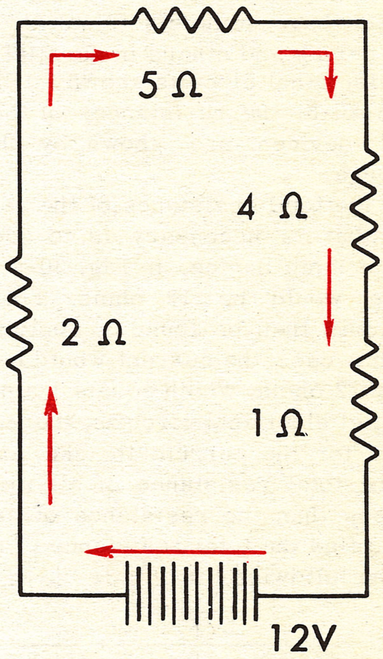
where E is the voltage, I the current in amperes and R the resistance in ohms. Transposing the factors of this equation, it may also be written

$$R = \frac{E,}{I} \text{ or}$$

$$I = \frac{E}{R}$$

Ohm's law is used extensively in checking and troubleshooting electrical circuits and parts in automobiles. For example: The current flowing through the field coils of a 12-v generator is 1.5 amperes. What is the resistance of the coils? Answer: 8 ohms.

Studying Ohm's law reveals that if the resistance of a circuit increases, while the voltage remains constant, the current will decrease. For example, if the connections at a starting battery are loose or corroded, a high resistance will be caused. The result will be that there will be insufficient current reaching the starting motor, lights or other units to provide proper operation.



30-4. In a series circuit the total resistance is the sum of the individual resistances.

TYPES OF CIRCUITS

There are three general types of electrical circuits: series, Fig. 30-4; parallel, Fig. 30-5; and a combination of the two, which is known as series-parallel, Fig. 30-6. All circuits, regardless of type consist of a source of electricity (a generator or a battery), various pieces of electrical equipment or devices and the necessary electrical conductors which connect the equipment or devices to the source of electrical power.

In a series circuit, Fig. 30-4, the current passes from the generator or battery to each of the devices in turn, and then to the other terminal of the generator. In that way, the current has only one path to flow. The amount of current will be the same in all parts of the circuit.

In parallel electrical circuits, Fig. 30-5, there will be more than one path for the current to flow. In such circuits one terminal of each device is connected to a common conductor leading to one terminal of the battery or generator, and the remaining terminals of each device are connected to another common conductor, which in turn is connected to the other terminal of the source of electrical power.

The series-parallel circuits, Fig. 30-6, are those which have some electrical devices connected in series and others in parallel.

In the electrical circuits shown in Figs. 30-4, 30-5, and 30-6, the resistances of the various electrical devices are shown by the Greek letter Omega.

To find the total resistance of the series circuit, all that is necessary is to add the resistance of each device. In Fig. 30-4, the total resistance would be 12 ohms. The current flowing would then be found by applying Ohm's law. In this case the current would be 12 volts divided by 12 ohms, which equals 1 ampere.

In parallel electrical circuits, there are several paths for the current to take, and consequently the total resistance of all the devices will be less than the resistance of any single device. To find the total resistance of a parallel circuit, the following formula is used:

$$R = \cfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} \text{ etc.}}$$

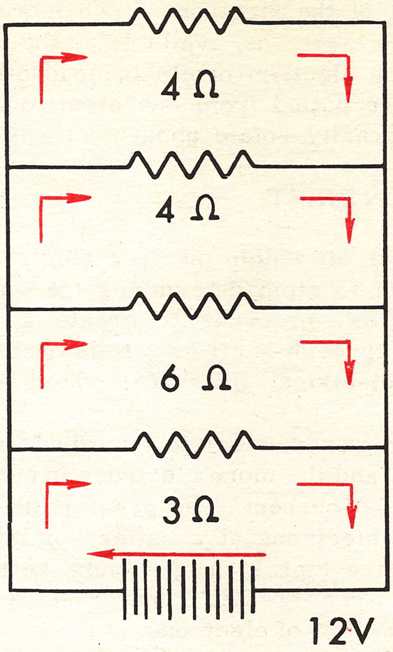
Using the values shown in Fig. 30-5 and substituting in the above formula we have

$$R = \cfrac{1}{\frac{1}{4} + \frac{1}{4} + \frac{1}{6} + \frac{1}{3}}$$

$$R = 1 \text{ ohm}$$

The total current flowing through the circuit will be 12 divided by 1, or 12 amperes. The current flowing through any single branch of a parallel circuit is found by dividing the voltage by the resistance of that particular branch. In Fig. 30-5 the current flowing in each branch would be 3,3,2 and 4 amperes. Adding these gives 12 amperes, which checks with the value found for the total circuit.

To make the calculations for a series-parallel circuit, the procedure is to treat each portion separately. Then having calculated the resistance of each parallel portion, those resistances are then added as would be the case in a simple series circuit.



30-5. Note how the current divides through the different branches of this parallel circuit.

In Fig. 30-6, the resistance of the upper parallel circuit becomes 3 ohms, the parallel circuit on the left of the diagram is 6 ohms. Adding these values to 3 ohms of the series circuit on the right side of the diagram makes a total of 12 ohms. Which incidentally is the same as the total resistance of the series circuit shown in Fig. 30-4.

VOLTAGE DROP

The decrease in voltage as current passes through a resistance is known as the voltage drop, and the sum of the individual drops in voltage is equal to the total voltage impressed on the circuit. Ohm's law is used to calculate the voltage drop in different parts of a circuit. In Fig. 30-4, as was previously pointed out, there is 1 ampere of current flowing. And as the voltage drop is equal to E = IR, the voltage drop across each of the resistances would be 1 X 2 = 2, 1 X 5 = 5, 1 X 4 = 4 and 1 X 1 = 1. Adding these drops in voltage we have 2 + 5 + 4 + 1 = 12 volts, which checks with the voltage impressed in the circuit.

ELECTRICAL WORK AND POWER

The electrical unit for measuring work is called the joule. One joule is equal to one ampere flowing for one second under the pressure of one volt.

To clarify this, it is necessary to understand that work is done when energy is expended, and is calculated as the product of the force and the distance through which it acts in overcoming resistance. Power is the rate of doing work.

An electrical force may exist without work being done and is the condition which exists between the terminals of a battery when no equipment is connected to the battery. When some equipment is connected to the terminals of the battery, current will flow and work will be done.

Power is the rate at which work is done, or:

$$\text{Power} = \frac{\text{work}}{\text{time}}$$

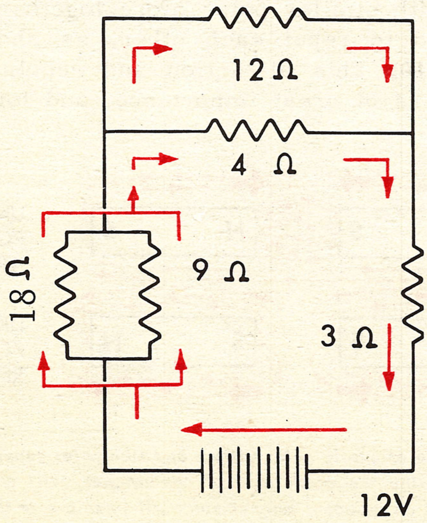
$$\text{Electrical power} = \frac{\text{electrical work}}{\text{time}}$$

The watt is the electrical unit of power and is equal to one joule of electrical work per second. Then:

$$\text{Watt} = \frac{\text{Joules}}{\text{Seconds}} = \frac{\text{Volts x Amperes x Seconds}}{\text{Seconds}}$$

Therefore: Watts = Volts x Amperes

For example: If in an automotive lighting circuit the current is 36 ampere and the voltage is 12, then the number of watts is 36 x 12 = 432 watts.



30-6. *A series-parallel circuit.*

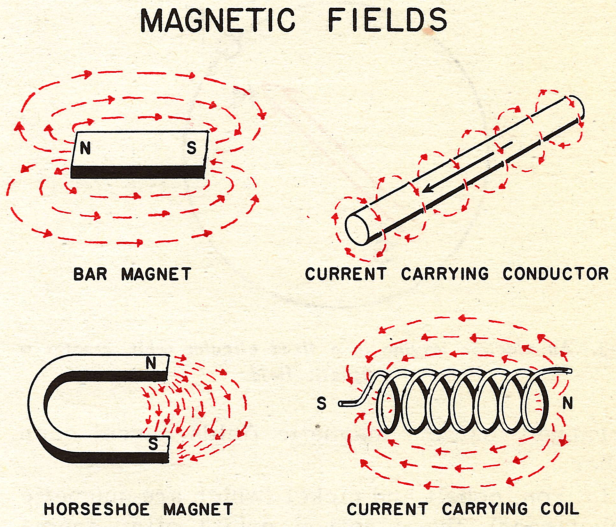
The unit for measuring mechanical power is the horsepower and experimentally it has been found that one horsepower is equal to 746 watts.

MAGNETISM

Magnetism, like electricity, is still a mystery. We know many laws governing its behavior and have applied it in the automotive field to starting motors, electric generators, ignition coils, voltage and current regulators, etc. However, no one knows just what magnetism is.

The effects of magnetism were first discovered when it was found that pieces of iron ore from certain parts of the world would attract each other and also other pieces of iron. In addition it was found that fragments of this ore when suspended in air would always point toward the North Star. The end of the piece of ore that pointed toward the north was called the "north pole" and the other end the "south pole."

The space surrounding a magnet and in which its effect can be noted, is known as its magnetic field, Fig. 30-7. This field is strongest close to the magnet, and gets progressively weaker as the distance from the magnet is increased.



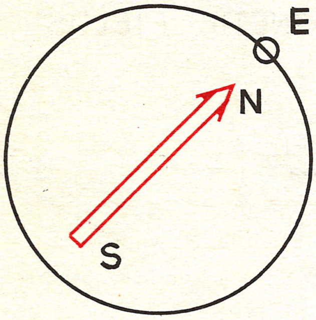
30-7. *Note the direction of the lines of force surrounding the magnets.*

The area or extent of the magnetic field can be determined by means of a compass, which will also show the direction of the lines of force. In Fig. 30-7 note how the lines of force leave the north pole of the magnets (and the coil) and re-enter at the south pole. Also note on the horseshoe magnet how the lines of force are more concentrated and stronger in the area immediately between the two poles of the magnet.

THEORY OF PERMANENT MAGNETS

While the effects, direction and extent of magnetic fields are easily studied, there is no actual knowledge as to why certain materials have magnetic properties and others do not. However the electron theory is generally accepted as giving the best explanation.

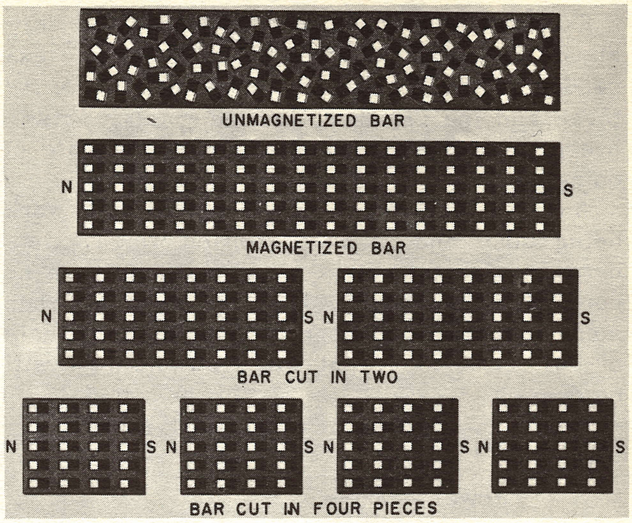
As previously explained in the unit on Fundamentals of Electricity, an electron carries a charge of negative electricity and is constantly moving in an orbit about the proton. It is therefore assumed that a known charge of electricity moving in an orbit is the same as a current of electricity flowing through the conductor. Thus, an electron moving in a fixed circular orbit creates a magnetic field, Fig. 30-8, which has a north pole on one side of the orbit and a south pole on the other. It is believed that more substances do not show magnetic properties because the orbits of the various electrons are so arranged that the magnetic fields cancel each other.



30-8. An electron moving in a fixed circular orbit, creates a magnetic field.

In iron, cobalt and nickel (which are magnetic substances) the electron orbits align themselves in parallel planes, and in the same direction when placed in a magnetic field, as shown in Fig. 30-9. This arrangement of the electron-created magnets produces a strong magnetic effect.

It is also interesting to note that soft iron will lose virtually all of its magnetic effect as soon as it is removed from the magnetic field. Hard steel will retain its magnetic characteristics for a long and indefinite period. Special alloys of tungsten, chromium and cobalt produce magnetic fields of considerably greater strength than other materials, and will also retain their magnetism for a longer period. Such alloys are used to form the magnets used in ignition magnetos and other specialized electrical equipment, where a strong magnetic field is required. Magnetic lines of force seem to penetrate all substances, and are deflected only by magnetic materials, or by another magnetic field. There is no insulator for magnetism or lines of force.

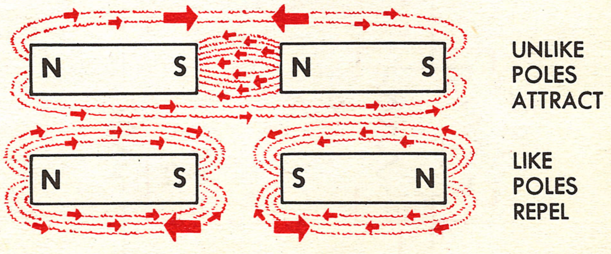


30-9. In magnetic substances the electron orbits align themselves in parallel planes and in the same direction when placed in a magnetic field.

Another interesting property of magnets is that when a magnet is cut in two, the individual pieces of the magnet will each have north and south poles, as shown in Fig. 30-9.

ATTRACTION AND REPULSION

When two permanent magnets are so placed that the north pole of one is close to the south pole of another magnet, they are found to attract each other. Also if the magnets are placed with similar poles close together, they are found to repel each other, as shown in Fig. 30-10. This attraction and repulsion of magnets is of great importance, and forms a



30-10. Unlike magnetic poles attract and like poles repel. Lines of force leaving the north pole of one magnet, will enter the south pole of an adjacent magnet since all lines are in the same direction. Also lines leaving similar poles are repelled as they have opposite direction.

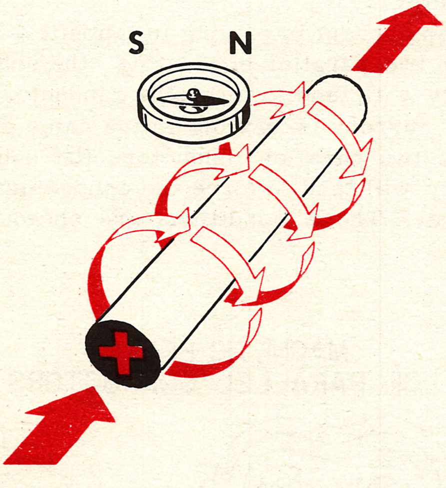
fundamental law of magnetism, namely: Like poles of magnets repel each other, and unlike poles attract each other.

PRODUCING MAGNETS AND MAGNETIC FIELDS

By stroking a piece of hardened steel with a natural magnet, it will be found that the piece of steel will soon become a magnet. Steel railroad tracks laid in a north-to-south direction are found to be magnetized as the result of lying parallel to the magnetic field of the earth.

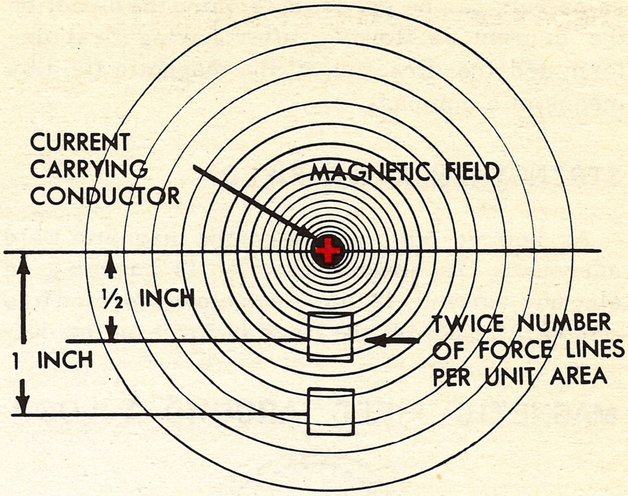
However, much stronger magnets and magnetic fields can be produced by electrical means. Placing a piece of steel in any strong magnetic field will cause it to become magnetized.

A magnetic field surrounds any conductor carrying an electrical current. The discovery of that fact resulted in the development of much of our electrical equipment. Such a field of force is always at right angles to the conductor, as can be shown by placing a magnetic compass close to a conductor of electricity. This is illustrated in Fig. 30-11. Since a magnetic force is the only force known to attract a compass needle, it is obvious that a flow of electric current produces a magnetic field similar to that produced by a permanent magnet. When making this experiment, direct current should be passed through the conductor. Alternating current should not be used as the magnetic field will change with each alteration of the current.



30-11. A magnetic field surrounds any conductor carrying an electrical current and the field is at right angles to the conductor.

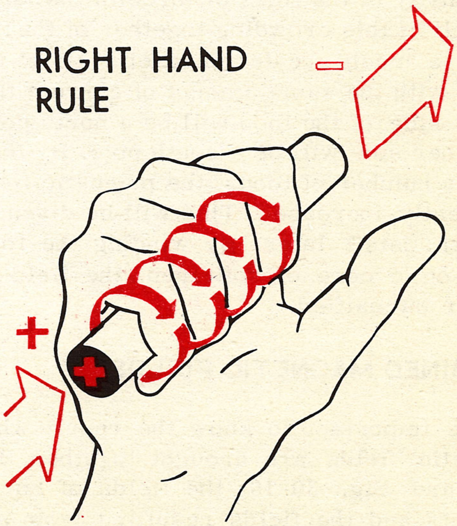
Not only is the field of force at right angles to the conductor, but it also forms concentric circles about the conductor, Fig. 30-12. Also, as the current in the conductor is increased, the field of force is increased. Doubling the current will double the strength of the field of force.


CURRENT CARRYING CONDUCTOR
MAGNETIC FIELD
½ INCH
1 INCH
TWICE NUMBER OF FORCE LINES PER UNIT AREA

30-12. A magnetic field forms concentric circles around a conductor carrying an electric current.

RIGHT HAND RULE

It is important to know the direction of the lines of force that surround a conductor. The direction of the lines of force is dependent on the direction the current is traveling in the conductor. To determine the direction of the lines of force, grasp the conductor with the right hand, and with the thumb extended in the direction the current is flowing. The fingers will then indicate the direction in which the lines of force surround the conductor, Fig. 30-13. The

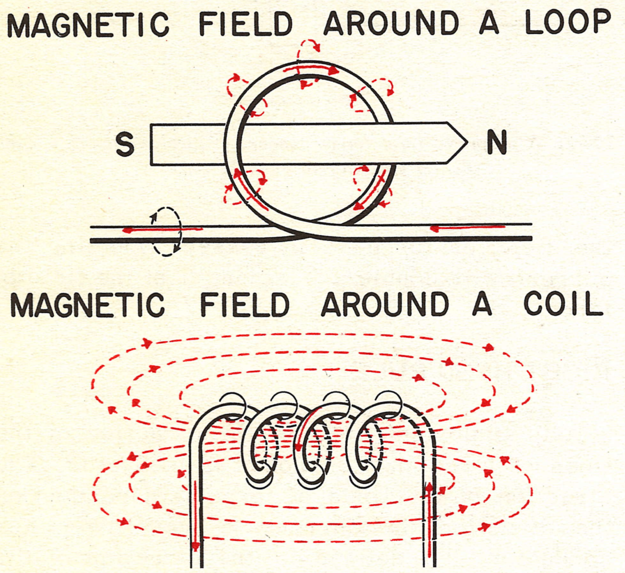


30-13. With the fingers of the right hand around the conductor, the fingers show the direction of the lines of force and the extended thumb shows the direction of the current in the conductor.

same rule can be used to determine the direction the current is flowing, after having first determined the direction of the magnetic field by means of a compass.

STRENGTHENING THE FIELD

As pointed out previously, the magnetic field surrounds the conductor which is carrying an electric current. If this conductor is formed into a loop, Fig. 30-14, the lines of force on the outside of the loop spread out into space, but the lines of force on the inside of the loop are confined and crowded together, thereby increasing the density of the lines of force in that area. As a result of this crowding together of the lines of force, a much greater magnetic effect is produced with the same amount of current flowing.


MAGNETIC FIELD AROUND A LOOP

MAGNETIC FIELD AROUND A COIL

30-14. Illustrating the magnetic field surrounding a single loop carrying current, and the field surrounding a coil of wire.

One side of the loop will be a north pole, and the other side will be a south pole. By increasing the number of loops, the magnetic field will be greatly increased. This will be discussed in greater detail later. By winding the loops or coils on a core of soft iron, the field is still further intensified.

COMBINED MAGNETIC FIELDS

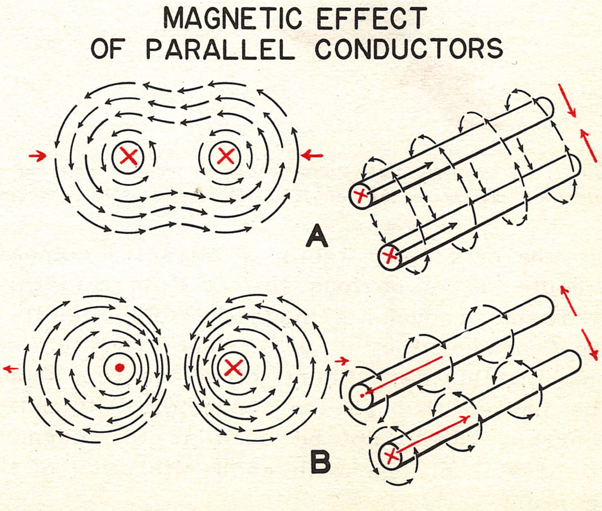
It is important to know the result when two magnetic fields are brought together. In Fig. 30-7 and Fig. 30-10, the fields of horseshoe magnets and the fields resulting from similar and from unlike poles were shown. The resultant magnetic fields surrounding adjacent conductors are also of interest.

The current flowing in opposite directions in two adjacent and parallel conductors is a typical condition, Fig. 30-15. In these illustrations, the + mark on the end of the conductor indicates that the current is moving away from the reader, and the in the end of the conductor indicates that the current is coming toward the reader.

A field of force will surround each conductor, and the direction of the field can be quickly determined by applying the right hand rule. As shown in B, Fig. 30-15, the field will be clockwise around one conductor and counterclockwise around the other. However, the area between the conductors, the lines of force are moving in the same direction.

As the amount of current is the same in both conductors, the total number of lines between the conductors is the same as the total number of lines outside the conductors. As the distance between the conductors is very little and limited, the lines of force will be very much crowded in that area. In other words, the density of the magnetic field will be greater between the conductors than it will be beyond the conductors. This condition is known as a case of unbalanced density, which will cause forces to act on the conductors.

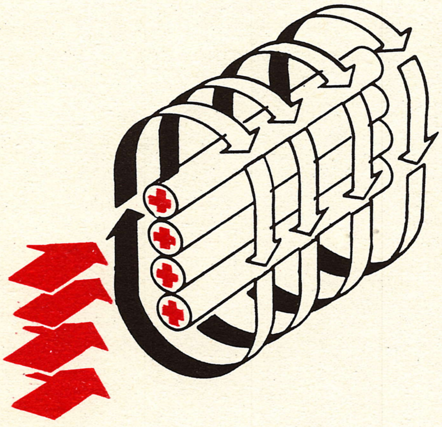
When current is moving in opposite directions in the two parallel conductors, the unbalanced density will tend to force the conductors apart. If the current is moving in the same direction in the two parallel conductors the unbalanced density will tend to force the conductors closer together. These conditions are shown in Fig. 30-15.


MAGNETIC EFFECT OF PARALLEL CONDUCTORS

30-15. With the current flowing in the same direction in the two conductors as shown at "A," the resultant magnetic field tends to force the two conductors together. If the current is flowing in opposite direction in the conductors as shown at "B," the magnetic field will force the conductors apart.

As was illustrated in A, Fig. 30-15, two parallel conductors carrying current in the same direction will tend to move closer together. In such a condition, the two conductors are acting basically like a single conductor, carrying a current equal to the sum of the two currents. As a result, twice the number of lines of force are created, as would be produced by either conductor with its original current. When several more current-carrying conductors are placed side by side, the effect as shown in Fig. 30-16, is produced. Here the lines of force join and surround all of the conductors. Such a magnetic pattern is obtained in a section of a generator field coil, a starter solenoid or an ignition coil.

The strength of the magnetic field surrounding a coil of wire is in direct proportion to the number of turns of wire in the coil, and the strength of the current. The product of the amperes flowing times the number of turns of wire, is a means of calculating the magnetizing force created, and is known as the ampere-turns.



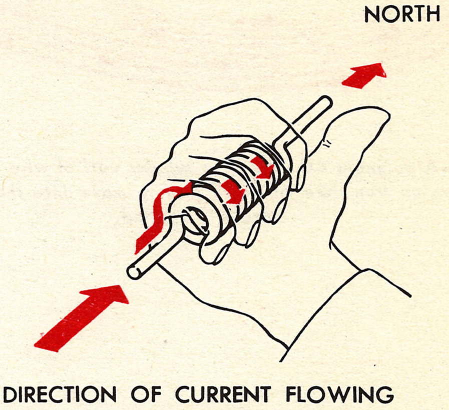
30-16. When several current-carrying conductors are placed side by side, the magnetic lines of force join and surround all of the conductors.

DETERMINING POLARITY

To determine the magnetic polarity of any coil or electromagnet when the direction of current flow is known, the right hand rule for coils may be used. To apply this rule, grasp the coil with the left hand so that the fingers extend in the direction the coil is wound and in the direction of current flow, Fig. 30-17. The thumb will then point toward the north pole created by the current flow through the coil. It must be remembered that both the direction of current flow, and the direction of coil winding, will determine the polarity of a coil. This is particularly important when connecting field coils of a generator together.

MAGNETIC CONDUCTIVITY

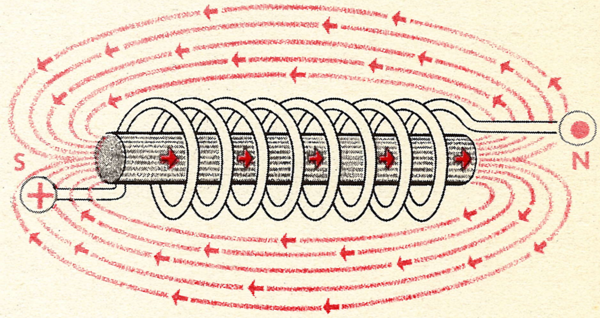
The conductivity of air for lines of force has been adopted as standard, and air is rated as having a permeability of one. Permeability of a substance is defined by Kelvin as "the ease with which lines of force may be established in any medium as compared with a vacuum." Briefly, it is the magnetic conductivity of a substance.



30-17. The right hand rule for coils may be used to determine the polarity of a current-carrying coil.

When a soft iron core is inserted in a coil to form a true electromagnet, Fig. 30-18, the magnetic flux or lines of force will be increased several hundred times. By means of the better conductor for the lines of force (the use of the iron core) more lines of force are created.

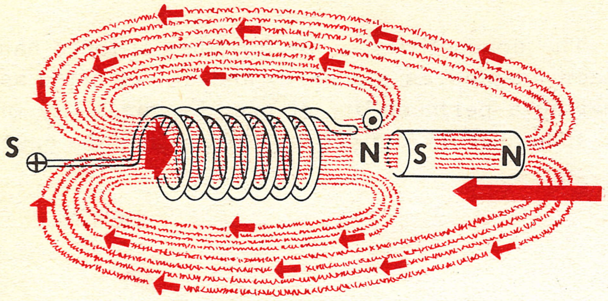
The field coils in generators and starters, regulator windings on iron cores and ignition coils all use this same principle.



30-18. The magnetic field of a coil can be strengthened many times by winding the coil on a core of soft iron. This is known as an electromagnet.

SOLENOIDS

A solenoid is a tubular coil of wire with an air core, and is designed to produce a magnetic field. In most cases the solenoid also includes an



30-19. A solenoid consists of a tubular coil of wire and usually includes an iron core which is free to move into the coil when current is applied.

iron core that is free to move in and out of the tubular coil, Fig. 30-19. Movement of the iron core is then used to operate some mechanism or switch. In the automotive field, it is usually used to shift a starting motor drive into engagement with the flywheel ring gear. When a solenoid is used to close the contacts of an electrical switch, it is called a magnetic switch.

In Fig. 30-19 it will be noted that the south pole of the iron core is adjacent to the north pole of the coil. The polarity of the movable iron core is induced by the lines of force from the coil. Because the adjacent poles of the coil and the core are of opposite polarity, there is an attraction which draws the movable core into the center of the coil whenever current flows.

QUIZ - ELECTRICITY, MAGNETISM

1-Will an electrified piece of rubber and an electrified piece of glass attract or repel each other?

2-Do similar electrified bodies attract or repel each other?

3-Atoms are divided into what particles?

4-Electrons have what type of electrical charge?
Positive_____Negative_____

5-The nucleus of an element consists of:
- a. Protons and neutrons
- b. Atoms and electrons
- c. Neutrons and electrons

6-Electrons in a conductor are closely held or are free electrons?

7-State Ohm's law.

8-If in a series circuit, there are four resistances, 4 ohms, 10 ohms, 5 ohms and 2 ohms, what is the total resistance?

9-Write the formula for determining the total resistance of a number of resistances in parallel.

10-If, in an automotive circuit there is a current of 6 amperes and the voltage is 12, how many watts are there?

11-How many watts are there in an electrical horsepower?
- a. 764 watts
- b. 464 watts
- c. 746 watts
- d. 674 watts

12-What is the name of the area surrounding a magnet?

13-Which of the following are magnetic substances?
- a. Iron
- b. Brass
- c. Nickel
- d. Lead

14-The magnetic field of force surrounding an electrical conductor is in what direction?
- a. Parallel to the conductor
- b. At right angles to the conductor

15-When you place the fingers of your right hand around a current carrying conductor, with extended thumb showing direction of current, what does direction of the fingers indicate?

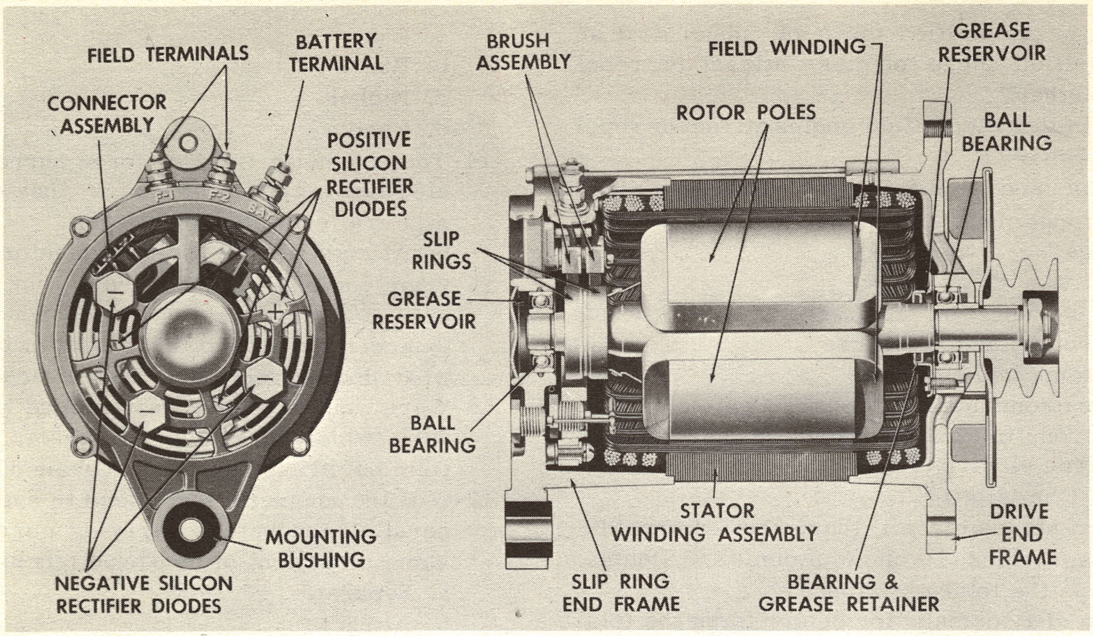
16-Were you to insert an iron core in a coil of wire which is carrying current, would the field be strengthened or weakened?

17-Will the magnetic force tend to separate two parallel conductors carrying current in the same direction, or tend to pull them together?
- a. Separate
- b. Attract

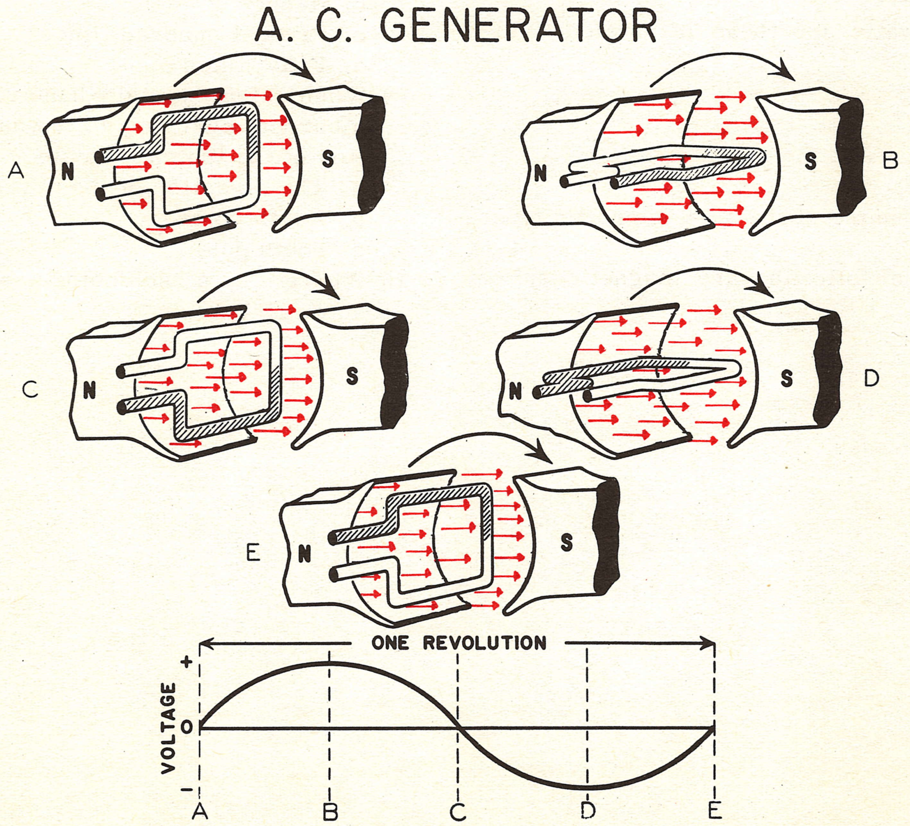
18-Inserting a magnetic core in a coil of wire carrying current will strengthen the field how much?
- a. Twice
- b. Reduce it
- c. Several hundred times
- d. Fifty times

19-When using the right-hand rule as applied to a current carrying coil, what does the direction of the thumb indicate?
- a. The direction of the current
- b. North pole
- c. South pole

20-Where is a solenoid used in a modern automobile?


FIELD TERMINALS
BATTERY TERMINAL
CONNECTOR ASSEMBLY
POSITIVE SILICON RECTIFIER DIODES
F1
F2
BAT
+
−
MOUNTING BUSHING
NEGATIVE SILICON RECTIFIER DIODES
BRUSH ASSEMBLY
SLIP RINGS
GREASE RESERVOIR
BALL BEARING
FIELD WINDING
ROTOR POLES
GREASE RESERVOIR
BALL BEARING
STATOR WINDING ASSEMBLY
SLIP RING END FRAME
BEARING & GREASE RETAINER
DRIVE END FRAME

31-1. Sectional view of Delco-Remy alternator. Note particularly the diodes, slip rings, rotor and stator.


A. C. GENERATOR
A
N
S
B
N
S
C
N
S
D
N
S
E
N
S
ONE REVOLUTION
VOLTAGE
+
0
−
A
B
C
D
E

31-2. Illustrating the variation in voltage that is induced in a coil as it is revolved in a magnetic field. The curve at the bottom of the figure shows the variation of voltage for each position of the revolving coil.

ELECTRIC GENERATORS

ELECTRIC GENERATORS

Alternating Current

An automotive generator of electricity, Fig. 31-1, is a machine that converts mechanical energy supplied by the engine, into electrical energy. This electrical energy is used for maintaining the storage battery in a fully charged condition, and for supplying electrical power to operate the ignition system and various pieces of accessory equipment.

ELECTROMAGNETIC INDUCTION

When a coil of wire is moved through a magnetic field a voltage will be induced or generated in that coil. This is the principle used in automotive electric generators, and is easily demonstrated by connecting the ends of a loop of wire to a sensitive electrical measuring instrument and moving the loop through a magnetic field.

Such a voltage can be produced either by moving the coil of wire through a stationary field, or by keeping the coil stationary and moving the magnetic field. If the field is being produced electrically, it can be caused to move by turning the current off and on. In general, an induced voltage is produced in a coil whenever there is a change in the lines of force passing through that coil.

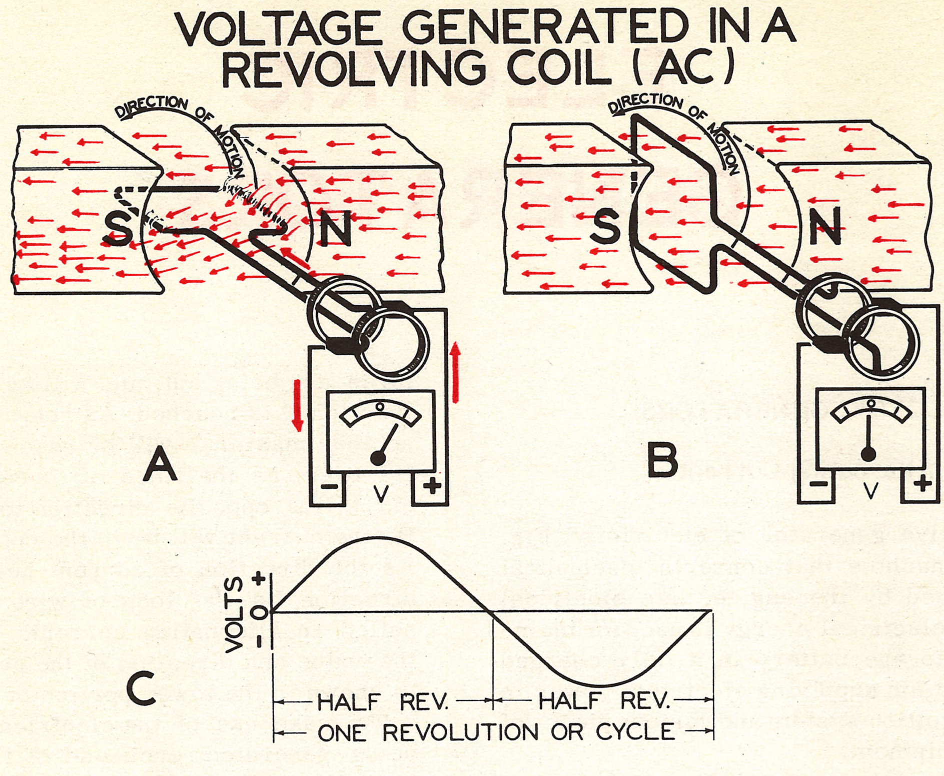
The lines of force being cut by a rotating coil is shown in Fig. 31-2. When the coil is in a vertical position as shown at A, Fig. 31-2, the lines of force surrounding the conductor are balanced, that is for that instant, no lines of force are being cut. Therefore no voltage will be induced in the coil. As the coil approaches position B, Fig. 31-2, an increasing number of lines of force will be cut and the generated voltage will increase until it reaches a maximum at position B. After passing position B, the voltage will start to decrease as fewer lines of force are being cut, and will become zero when position C is reached. As rotation is continued, another maximum will be reached at position D. However, as the lines of force are now being cut in the opposite direction to that of position B, the current will be in the opposite direction. As the direction of current keeps changing its direction as the loop of wire is rotated it is called an alternating current. The variation in the value and direction of the generated voltage is shown in the lower portion of Fig. 31-2.

To make use of the electrical energy that is being generated, each end of the coil is connected to a ring which rotates with the coil of wire. Contact with these rotating rings is made by brushes which bear against the rings as shown in Fig. 31-3. Note the direction of the generated voltage as shown by the voltmeter connected to the brushes and also the curve at C Fig. 31-3.

In an alternating current generator, or alternator as it is known, the magnetic field is rotated and the voltage is generated in the stationary coils, Fig. 31-1. This has the advantage that heavy currents do not have to pass through brushes and collector rings.

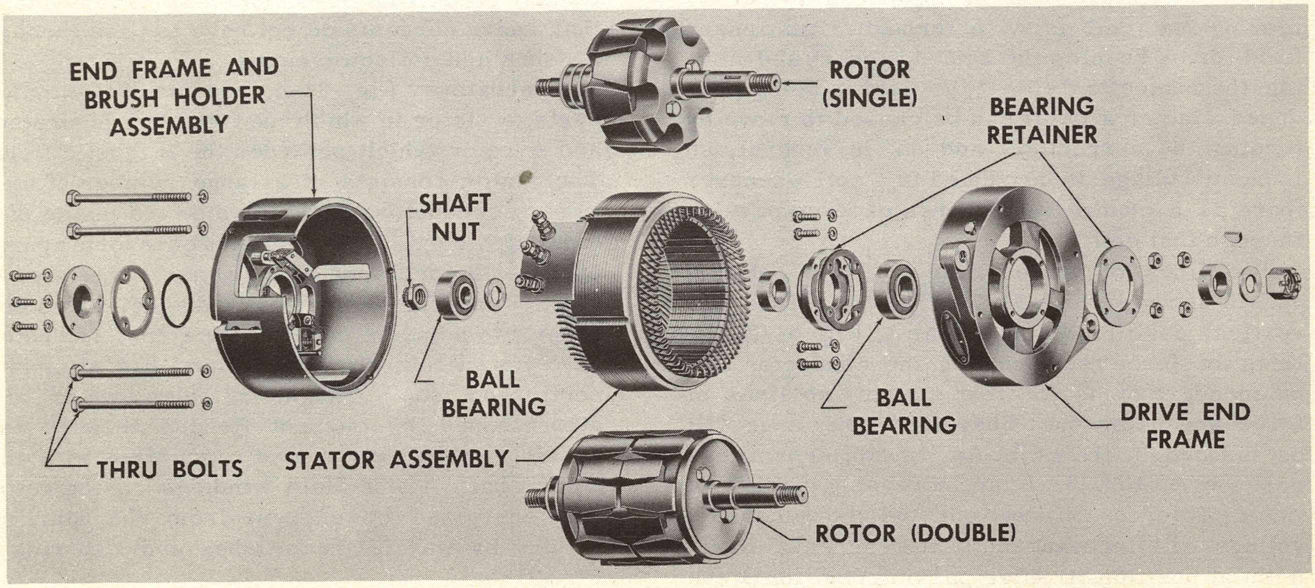
Alternators, Fig. 31-4, consist of two major parts, a stator in which the voltage is generated, and a rotor which provides the magnetic field. The stator consists of a large number of stationary conductors assembled on the inside of a laminated core. This laminated core forms parts of the exterior frame of the generator, and provides a path for the flow of the magnetic flux between two adjacent poles of the rotor. The rotor revolves within the stator, and has alternate north and south magnetic poles which are strengthened by current flowing through the windings which are wound concentric with the rotor shaft. These field windings on the rotor are energized by current from the starting battery by way of the brushes and slip rings, Fig. 31-5.

In the simplified alternator shown in Fig. 31-2,


VOLTAGE GENERATED IN A REVOLVING COIL (AC)
DIRECTION OF MOTION
S
N
A
−
V
+
DIRECTION OF MOTION
S
N
B
−
V
+
VOLTS
+
0
−
C
HALF REV.
HALF REV.
ONE REVOLUTION OR CYCLE

31-3. Each end of the rotating loop, or rotor is connected to a collector ring. The external circuit or load is then connected to the brushes.

only a single conductor or loop and the voltage generated is shown in the same illustration. An alternator with all the conductors connected in series would produce a similar wave of alternating voltage and is known as a single phase alternator. Alternators as used for automotive purposes, however are of the three phase type. That is, three separate windings are provided in the stator which are connected as shown in Fig. 31-6. Each of these windings then generates a

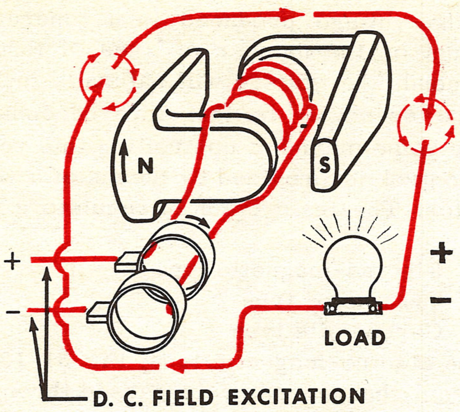

END FRAME AND BRUSH HOLDER ASSEMBLY
ROTOR (SINGLE)
BEARING RETAINER
SHAFT NUT
BALL BEARING
BALL BEARING
DRIVE END FRAME
THRU BOLTS
STATOR ASSEMBLY
ROTOR (DOUBLE)

31-4. Exploded view of automotive alternator. Two types of rotors are shown, single and double types.

separate voltage as shown in Fig. 31-7. Note that each phase is equally spaced from the other.

FIELD EXCITATION

To strengthen the magnetic field, the field circuit on the rotor is connected to the battery



31-5. Current for the field excitation is supplied through the slip rings from the starting battery.

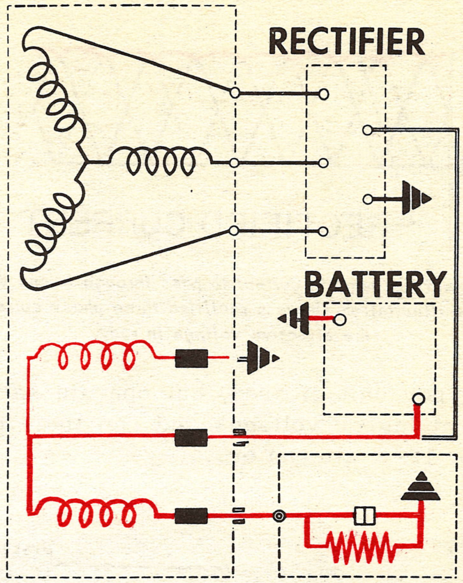
or the direct current side of the rectifier, Fig. 31-5. This connection is made through brushes and solid slip rings mounted on the shaft of the rotor. The direct current voltage of the system is controlled by varying the amount of field current which excites the generator.

To provide voltage control at high speed, many alternators have a reverse field winding. Electrically, this reverse winding is a high resistance shunt winding connected in parallel with the main field winding.

The reverse winding is so wound and connected that when the generator is charging, current flow in the reverse winding creates a magnetic field which opposes that created by current flow in the main winding.

RECTIFIERS

As alternating current cannot be used to charge a starting battery or provide current to produce the magnetic field in an alternator, it is necessary to change the alternating current produced in the stator to direct current. This conversion is done by means of a rectifier. A rectifier is a device which permits current to flow through it in only one direction. When the three-phase output of an alternator is passed through the rectifier, instead of the voltage of each phase ranging from positive to negative and back to positive again, only the voltage in one direction will pass through. The result is as shown in Fig. 31-8. Note that while the voltage of each phase ranges from zero to maximum, the combined voltages of all the phases varies very little.



31-6. Note the stator windings which are in the form of a "Y."

TYPES OF RECTIFIERS

Different types of rectifiers in use include:

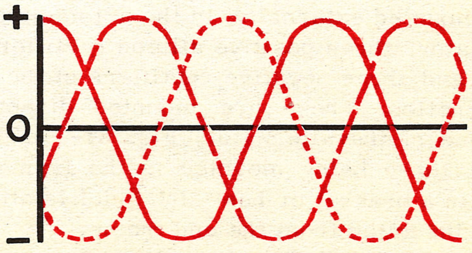
1. Magnesium-copper sulphide
2. Selenium
3. Silicon-diode

MAGNESIUM-COPPER SULFIDE RECTIFIER

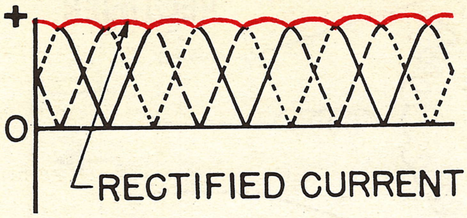
The rectifier plates of this type of rectifier, Fig. 31-9, have a comparatively high current carrying capacity per unit of area, but three volts is the maximum each plate can stand. For that reason, this type rectifier is used only on alternators of 6-v capacity.

SELENIUM RECTIFIERS

The rectifier plates used in the selenium rectifier have a comparatively low current ca-

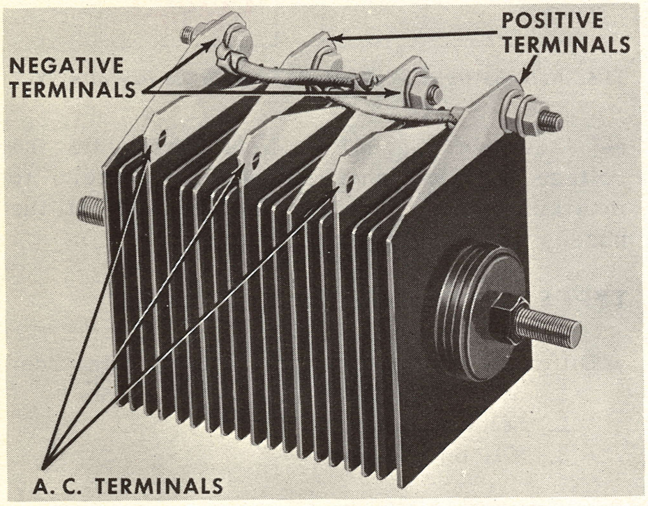


31-7. Each winding of the stator generates a separate voltage.



31-8. A rectifier permits current to pass through in one direction only. The illustration shows a rectified three phase current with the effective voltage in red.

pacity per unit of area, but operate satisfactorily at higher voltages and can therefore be used on 12-v alternators.


POSITIVE TERMINALS
NEGATIVE TERMINALS
A. C. TERMINALS

31-9. Magnesium copper sulfide type rectifier. This type unit is limited to alternators af 6 volts.

SILICON RECTIFIER

The silicon rectifier, or silicon-diode rectifier, Fig. 31-10, to give its full name, is the most recent type of rectifier to be developed and because of its small size it is built into the frame of the alternator, Fig. 31-11, whereas the other types of rectifiers, being of the plate type, are relatively large in size and are therefore mounted externally. In the automotive type alternator, three positive silicon rectifiers are used, and three negative rectifiers of the same construction. These are mounted directly on one end of the alternator, Fig. 31-1 and Fig. 31-11, three being mounted in the frame, and three in a bracket or heat sink which is attached to but insulated from the end frame.

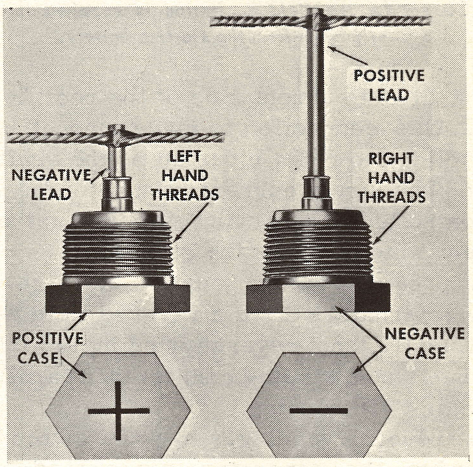
The silicon diodes, Fig. 31-10, are plainly marked with a + or - sign to identify the polarity of the case. On a generator to be used on a negative grounded system, the negative case diodes are mounted into the slip ring end frame, and the positive case diodes are mounted in the heat sink. Diodes with a negative case have positive polarity leads, while positive case diodes have negative polarity leads.

REGULATORS FOR ALTERNATORS

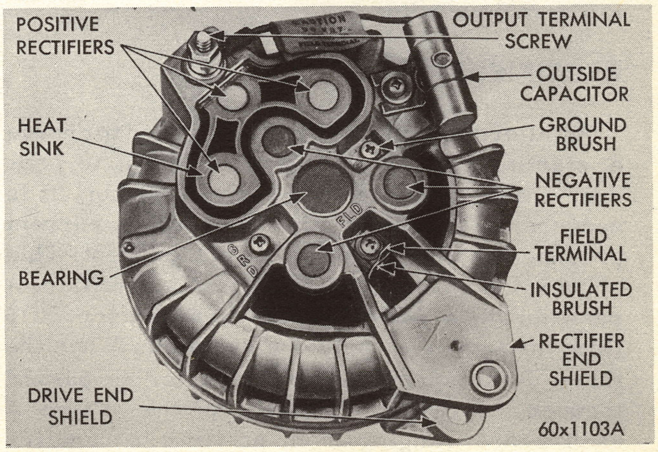
As the voltage produced in a generator is dependent on the number of lines of force cut per second, the voltage will naturally increase with the speed. It is therefore necessary to provide some means of controlling this voltage. Such control is provided by means of a voltage regulator. The main types of regulators in use are:

1. Electro-magnetic type
2. Transistor type
3. Carbon pile type

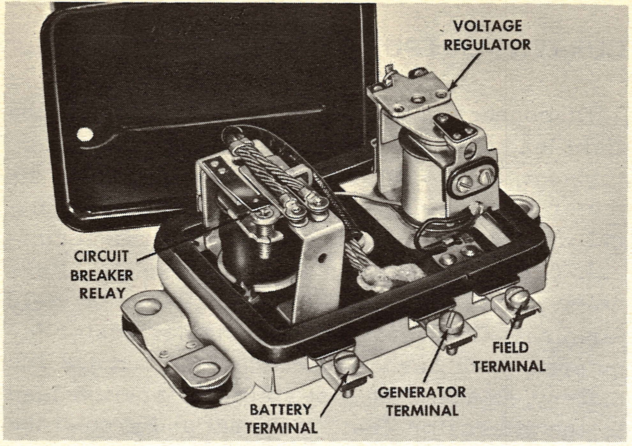
In the electro-magnetic type, Fig. 31-12, current from the generator is passed through the


POSITIVE LEAD
NEGATIVE LEAD
LEFT HAND THREADS
RIGHT HAND THREADS
POSITIVE CASE
NEGATIVE CASE
+
—

31-10. Showing the silicon diode rectifier with its positive and negative markings.


POSITIVE RECTIFIERS
OUTPUT TERMINAL SCREW
OUTSIDE CAPACITOR
HEAT SINK
GROUND BRUSH
NEGATIVE RECTIFIERS
FIELD TERMINAL
BEARING
INSULATED BRUSH
RECTIFIER END SHIELD
DRIVE END SHIELD
FLD
60x1103A

31-11. Note silicon diode rectifiers built into the end plate of of this alternator.



31-12. Two unit standard regulator for use on alternator. (Delco-Remy)

windings of an electro-magnet which in turn will open or close the circuit of the generator field. In that way, the magnetic lines of force cutting the stator windings are controlled, and the voltage is limited to the desired value. This type of regulator gives good service, but the contact points which open and close the circuit, become pitted making it necessary to replace or recondition the unit.

The transistor type unit, Fig. 31-13, has no moving parts and operates electrically and consequently has a long life. In addition, the operation of the transistor type of regulator is not affected by humidity or temperature.

The complete transistor type regulator consists of transistors, diodes, condensers and resistors. Some models employ two filter condensers, while others use only one.

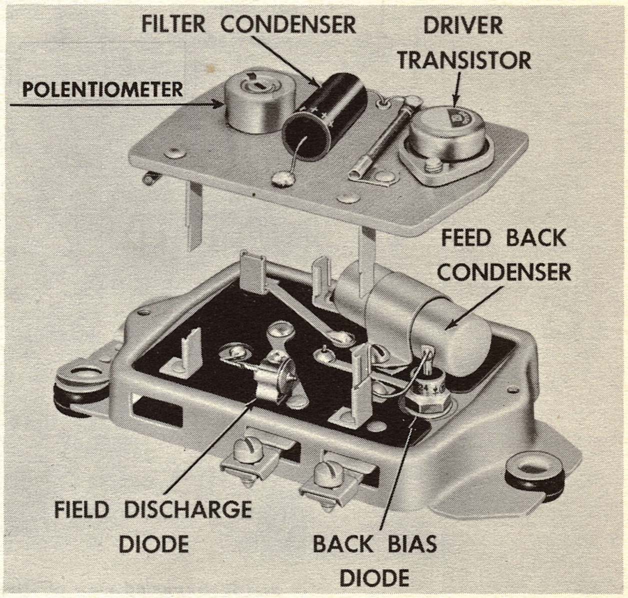
CARBON PILE REGULATORS

In the carbon pile type regulator, a stack or pile of small flat carbon discs is inserted in series with the alternator field circuit. Control of the charging system voltage is obtained by varying the resistance of the carbon stack without interrupting the flow of current. The regulator contains a field exciter relay, a circuit breaker relay and a voltage regulator unit, also a condenser connected across the field exciter relay contacts and a system voltage rheostat connected in series with the voltage regulator shunt winding.

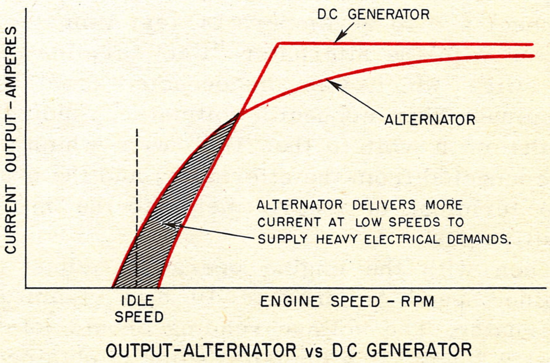
ALTERNATORS VS DC GENERATORS

One of the major advantages of the alternator over the familiar direct current generator, is that at low speeds the alternator will produce an appreciable amount of current, while the direct current generator will develop little or none, Fig. 31-14. If by means of a different size pulley on the generator, its speed is increased in relation to the engine speed, the result will be that at higher engine speeds, centrifugal force will throw the wires from the rotating armature. Another difficulty of the DC generator is that as the current passing through the armature increases, arcing at the brushes becomes severe. This in turn results in rapid commutator and brush wear.

Another major advantage of the alternator is that the field, which is rotating, carries only a few amperes of current. Furthermore, the field current of approximately 2 to 3 amperes is supplied through slip rings and consequently there will be no arcing at the brushes. With the DC generator, 25 to 45 amperes are passed through the brushes and commutator, and arcing is therefore difficult to overcome.



31-13. Transistor type regulator. (Delco-Remy)



31-14. Comparison of output of direct current generator and alternator.

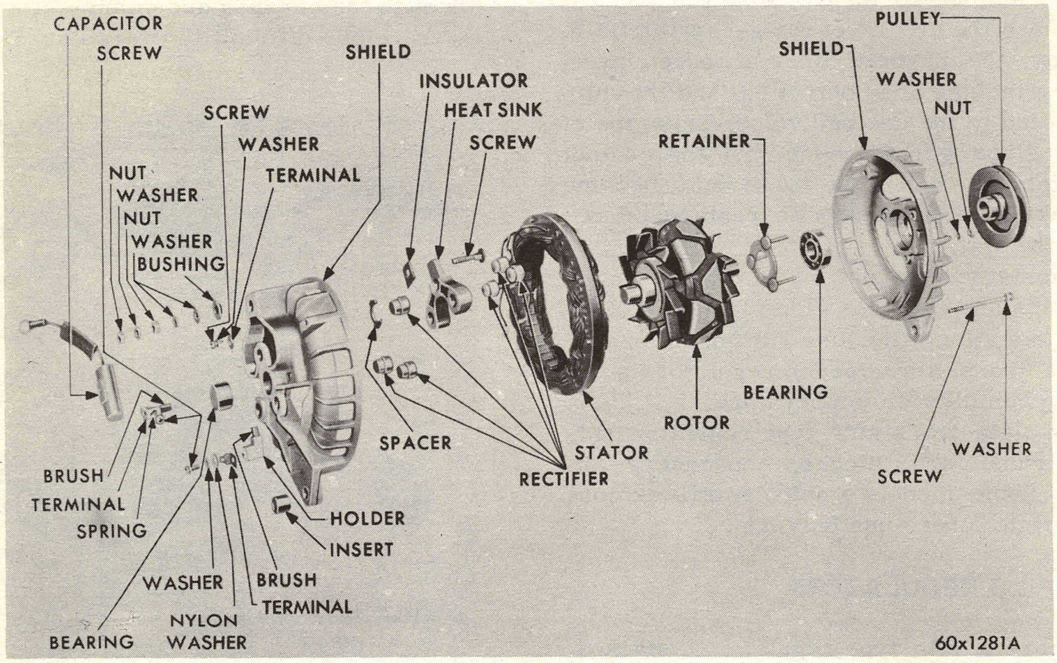
Automotive alternators are also designed so that the windings on the rotor cannot be thrown out at high rotational speeds.

SERVICING THE ALTERNATOR (With Silicon Type Rectifier)

When servicing and checking an alternator on the vehicle, it is important not to ground the alternator field circuit as this will result in damage to the voltage regulator.

With the battery fully charged, and the engine at normal operating temperature, make a charging resistance test as follows: Disconnect the wire from the "Bat" terminal of the alternator. Connect a 0 to 50 ampere DC test ammeter in series with the alternator "Bat" terminal and the wire which was disconnected from that terminal. Then connect a voltmeter, reading in tenths of a volt to the "Bat" wire which was disconnected from the alternator, and the negative terminal of the voltmeter to the battery positive post.

Then with the engine operating, adjust the engine speed to produce 10 amp. from the alternator. The voltage reading should not exceed 0.2 volt. If a higher reading is obtained a high resistance is indicated and all connections should be cleaned and tightened.


CAPACITOR
SCREW
SHIELD
INSULATOR
HEAT SINK
SCREW
SCREW
WASHER
TERMINAL
NUT
WASHER
NUT
WASHER
BUSHING
PULLEY
SHIELD
WASHER
NUT
RETAINER
BEARING
ROTOR
STATOR
RECTIFIER
SPACER
WASHER
SCREW
BRUSH
TERMINAL
SPRING
HOLDER
INSERT
WASHER
BRUSH
TERMINAL
NYLON WASHER
BEARING
60x1281A

31-15. Exploded view of Plymouth alternator. These are held together by means of through bolts passing through the assembly.

CURRENT OUTPUT TEST

Disconnect battery ground cable and also the field lead at the alternator and at the regulator. Connect a 0 to 50 ampere scale DC test ammeter in series with the alternator "Bat" terminal and the wire disconnected from that terminal. Connect a jumper wire between the alternator "Bat" terminal and the alternator field terminal. Connect a battery-starter tester (equipped with carbon pile rheostat) across the battery. Connect the test voltmeter positive lead to the alternator "Bat" terminal and ground the voltmeter negative lead to the alternator housing. Connect the battery ground connection. Adjust the engine speed to value specified for that alternator and adjust rheostat to maintain 15 volts. The current should meet the specified value.

ALTERNATOR INSPECTION

The frequence of inspection is dependent entirely on operating conditions. High speed operation, high temperatures, dust and dirt all tend to increase wear on brushes, slip rings and bearings.

At approximately 5000 mile intervals, the alternator should be carefully inspected to make sure that the brushes, slip rings and bearings are in good condition. In addition, the driving belt should be checked for tension and the mounting bolts for tightness. Because of the higher inertia of the rotor as compared to the armature of a direct current generator, drive belt tension is more critical. When cleaning the slip rings, 400 grain polishing cloth should be used. Emery paper should never be used. When brushes are worn to one-half their original length they should be replaced. If the slip rings are rough or out-of-round, they should be trued on a lathe.

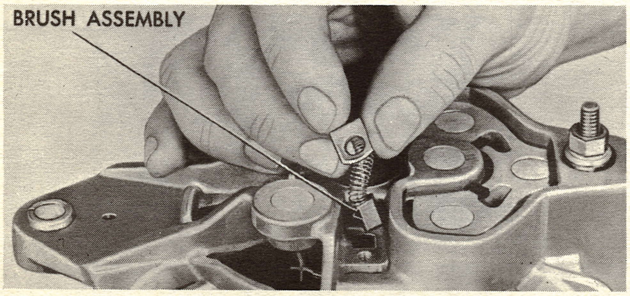
ALTERNATOR DISASSEMBLY

Alternators are held together by means of through bolts which pass through the units from end to end, Fig. 31-4. Removing the through bolts will permit the separation of the end frames. In the case of the Chrysler type of alternator, Fig. 31-15, the brushes should first be removed, Fig. 31-16. These are held in position by means of retaining screws. In the case of the Delco-Remy type alternator, when removing the drive end frame and rotor assembly, insert a through bolt into the slip ring end frame, and lift the brushes from the slip ring while separating the alternator parts.

TESTING THE STATOR

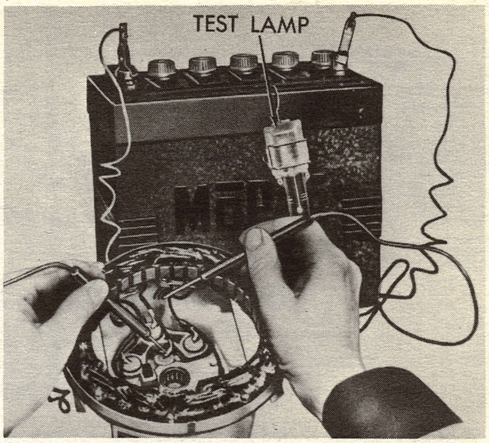
Stator windings of automotive alternators are of the Y type. As shown in Fig. 31-6, there are three windings having one common connection, with each winding supplying one phase.

Each of these windings should be tested for grounds, opens or shorts. To check for a grounded winding, connect one prod of a test lamp to the frame, and then touch the other prod to each terminal or stator lead. If the lamp lights, the stator winding is grounded.



31-16. Removing a brush from the Plymouth alternator.

To test the windings for continuity, place one test prod at the common connection of the three windings, and the other test prod to the other end of the windings in turn, Fig. 31-17. Make sure the free ends of the windings are not connected to the rectifiers. The test lamp should light when the test prod contacts each of the three leads. If it does not light, the stator winding is open.



31-17. Testing the stator windings for continuity.

TESTING THE ROTOR

The rotor should also be tested for grounds, shorts and opens. To check for grounds, connect a test lamp from either slip ring, and to the rotor shaft or laminations. If the lamp lights, the field windings are grounded.

To check for opens, place one prod of the 110-v test lamp on one slip ring, and the other prod on the other slip ring. If the test lamp does not light, the rotor windings are open.

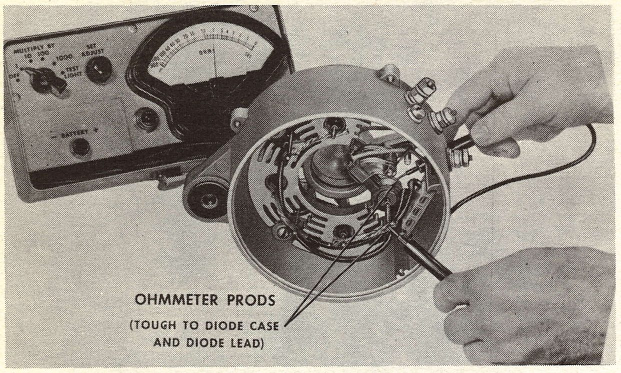
The best method of checking the rotor windings for short circuits, is by connecting a starting battery and ammeter in series with the two slip rings. The ammeter reading should then be compared with the specifications of that particular alternator. An ammeter reading above the specified value indicates shorted windings.

CHECKING SILICON-DIODE RECTIFIERS

An ohmmeter is used to check the silicon-diode rectifiers as used on Delco-Remy types of automotive alternators. To check a diode for shorts, connect the negative lead of the ohmmeter to the negative case of the diode, Fig. 31-18. Connect the positive lead of the ohmmeter to the positive lead on the diode. Reverse the connections for positive case diodes. Ohmmeter readings may vary greatly, but if the reading is less than 300 ohms, the diode should be replaced.

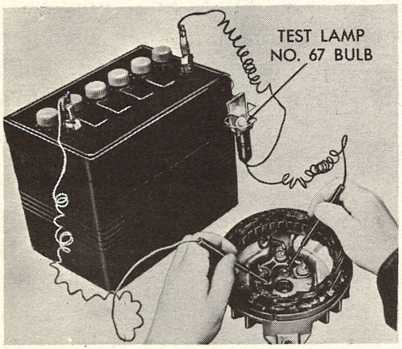
Make sure that the leads on the diodes are not loose.

To check for an open circuit, connect the negative lead of the ohmmeter to the positive lead of the diode, and the positive lead of the ohmmeter to the negative lead of the diode. Reverse the connections for positive case diodes. If the ohmmeter reads an infinite resistance, the diodes are open and must be replaced.


OHMMETER PRODS
(TOUGH TO DIODE CASE
AND DIODE LEAD)

31-18. Testing diode on Delco-Remy alternator with an ohmmeter.

Rectifiers as used on the Chrysler type of alternator are tested by means of a 12-v battery and a No. 67 light bulb. With the light bulb connected in series with the battery, Fig. 31-19, contact the outer case of the rectifier with one test prod, and the wire in the center of the rectifier with the other test prod. Then reverse the position of the prods. If the test lamp lights in one position and not in the other, the rectifier is satisfactory. If the test lamp lights in both positions of the test prods, the rectifier is not satisfactory and should be replaced.


TEST LAMP
NO. 67 BULB

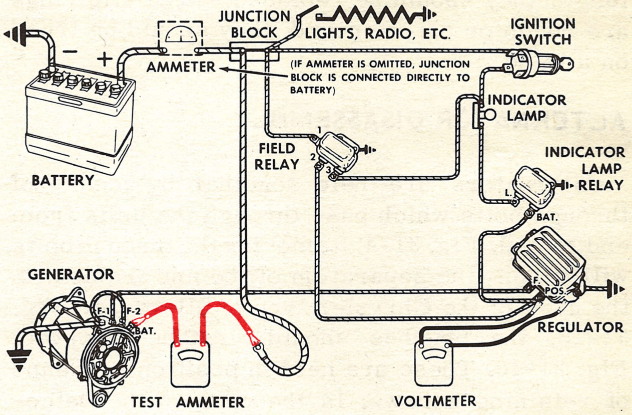
31-19. Checking a diode on a Plymouth alternator with a test lamp.

TRANSISTOR TYPE REGULATORS

The transistor as used on automotive regulators is an electrical device which limits the generator voltage to a preset value by controlling the generator field current.

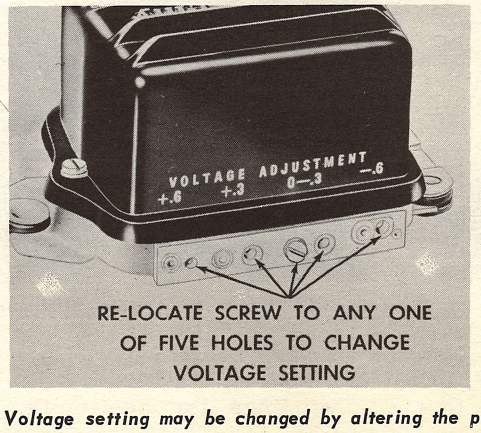
The complete Delco unit consists principally of transistors, diodes, condensers and resistors, Fig. 31-13. As was pointed out previously, the diode is a device which permits current to pass through it in one direction only.

To check the voltage setting of the transistor regulator, connect the test voltmeter and ammeter as shown in Fig. 31-20. If voltage reading is too low with engine operating at 1500 r.p.m. the setting may be increased by adjusting the screw in the base of the regulator as shown in Fig. 31-21. Voltage can be adjusted in 0.3 volt steps without removing the regulator cover. Under extreme conditions, it may be necessary to make further adjustment by means of the potentiometer shown in Fig. 31-13.


JUNCTION
BLOCK
LIGHTS, RADIO, ETC.
IGNITION
SWITCH
−
+
AMMETER
(IF AMMETER IS OMITTED, JUNCTION
BLOCK IS CONNECTED DIRECTLY TO
BATTERY)
INDICATOR
LAMP
1
FIELD
RELAY
2
3
INDICATOR
LAMP
RELAY
L.
BAT.
BATTERY
GENERATOR
F-1
F-2
BAT.
F.
POS.
REGULATOR
TEST AMMETER
VOLTMETER

31-20. Testing voltage setting of voltage regulator.

To check for a shorted field discharge diode, connect the ohmmeter as shown in Fig. 31-22. Zero resistance indicates a shorted diode. To check for open power transistor, connect ohmmeters as shown in steps 1 and 2, Fig. 31-22. If the resistance in either step is more than 50

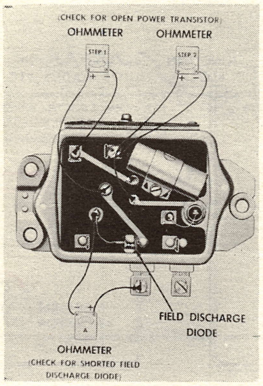

VOLTAGE ADJUSTMENT
+.6
+.3
0
−.3
−.6
RE-LOCATE SCREW TO ANY ONE
OF FIVE HOLES TO CHANGE
VOLTAGE SETTING

31-21. Voltage setting may be changed by altering the position of the screw in the base of the regulator. (Delco-Remy) ohms, the transistor is "open."

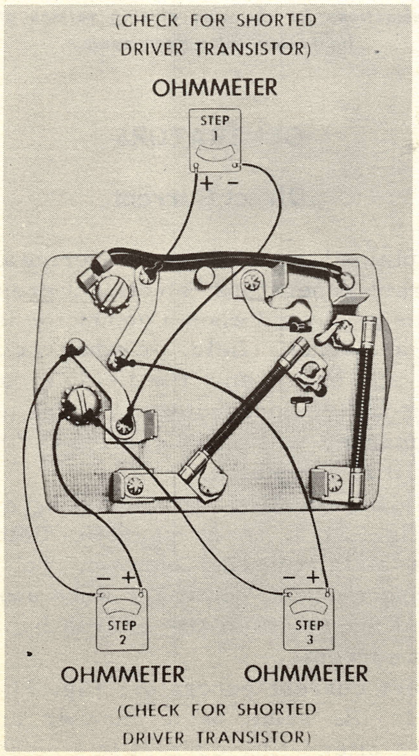
Connections for shorted driver transistor test are shown in Fig. 31-23. If the resistance is zero for any position of the ohmmeter shown, the driver transistor is shorted.

A zero resistance reading when the ohmmeter is connected as shown in Fig. 31-24, part A, indicates a shorted diode. To check for open voltage divider resistor, connect as shown at B, Fig. 31-24. If ohmmeter indicates infinite resistance, the potentiometer or the resistor is open.

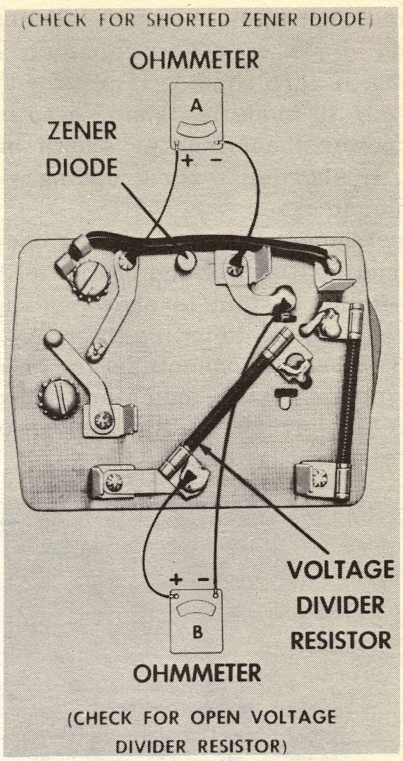
Five different tests of the regulator can be made by connecting the ohmmeter as shown in Fig. 31-25. In the case of an open circuit, the resistance will be infinite, while a shorted feed back condenser will have zero resistance.


(CHECK FOR OPEN POWER TRANSISTOR)
OHMMETER
OHMMETER
STEP 1
STEP 2
+ −
+ −
− +
A
FIELD DISCHARGE DIODE
OHMMETER
(CHECK FOR SHORTED FIELD DISCHARGE DIODE)

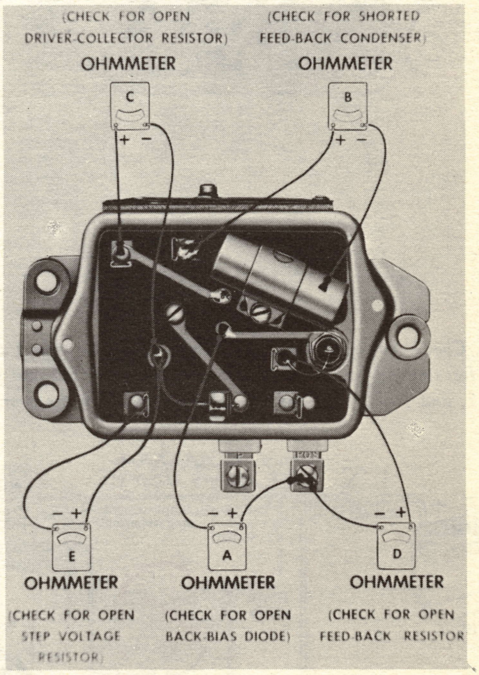
31-22. Connections for check of open power transistor.


(CHECK FOR SHORTED DRIVER TRANSISTOR)
OHMMETER
STEP 1
+ −
− +
− +
STEP 2
STEP 3
OHMMETER
OHMMETER
(CHECK FOR SHORTED DRIVER TRANSISTOR)

31-23. Check for shorted driver transistor.


(CHECK FOR SHORTED ZENER DIODE)
OHMMETER
A
+ −
ZENER DIODE
+ −
B
VOLTAGE DIVIDER RESISTOR
OHMMETER
(CHECK FOR OPEN VOLTAGE DIVIDER RESISTOR)

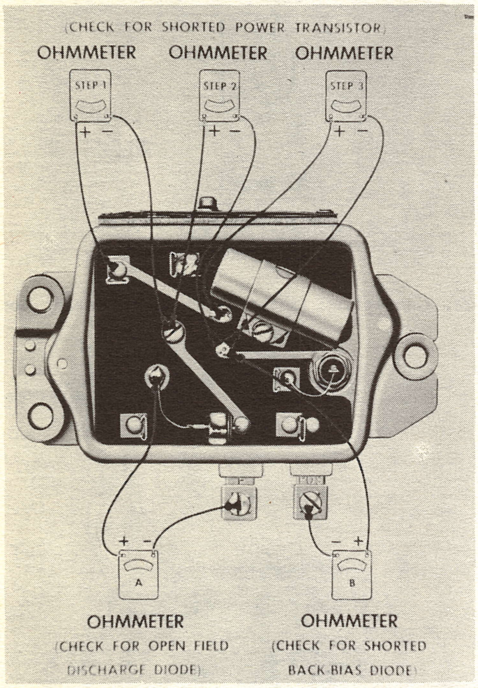
31-24. Connections for testing for shorted zener diode.


(CHECK FOR OPEN DRIVER-COLLECTOR RESISTOR)
OHMMETER
C
+ −
(CHECK FOR SHORTED FEED-BACK CONDENSER)
OHMMETER
B
+ −
− +
E
OHMMETER
(CHECK FOR OPEN STEP VOLTAGE RESISTOR)
− +
A
OHMMETER
(CHECK FOR OPEN BACK-BIAS DIODE)
− +
D
OHMMETER
(CHECK FOR OPEN FEED-BACK RESISTOR)

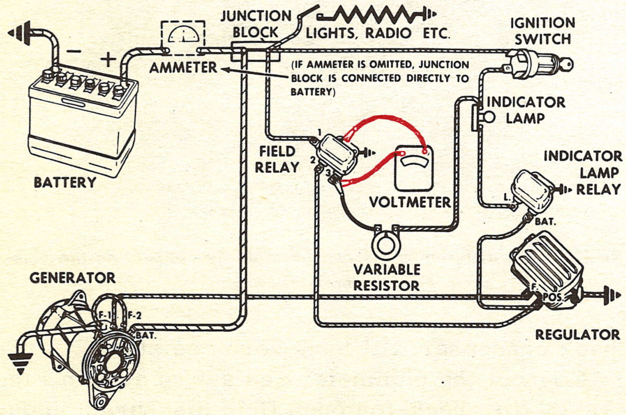
31-25. Five different tests can be made by connecting the ohmmeter as shown.

Connect the ohmmeters as shown at A in Fig. 31-26, to check for open field discharge diode. If the reading is over 50 ohms, when test A is made, the diode is open. If such is found, also check for shorted power transistor. For shorted back bias diode connect ohmmeter as at B, Fig. 31-26. If zero reading is obtained the diode is shorted. If such is found, also check for shorted power transistor as shown in steps 1, 2 and 3. If shorted, a zero reading will be obtained in each case.

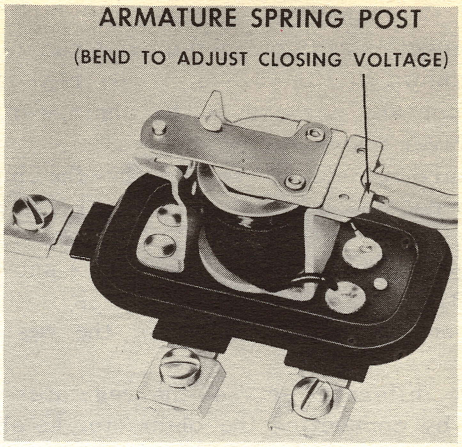
The instrument connections for checking the closing and sealing voltage of the field relay of a Delco-Remy system is shown in Fig. 31-27, and the method of adjusting the relay is shown in Fig. 31-28. The connections for checking the closing voltage of the indicator light relay are shown in Fig. 31-29, and the method of adjusting the relay in Fig. 31-30.


(CHECK FOR SHORTED POWER TRANSISTOR)
OHMMETER
OHMMETER
OHMMETER
STEP 1
STEP 2
STEP 3
+ −
+ −
+ −
+ −
− +
A
B
OHMMETER
(CHECK FOR OPEN FIELD DISCHARGE DIODE)
OHMMETER
(CHECK FOR SHORTED BACK BIAS DIODE)

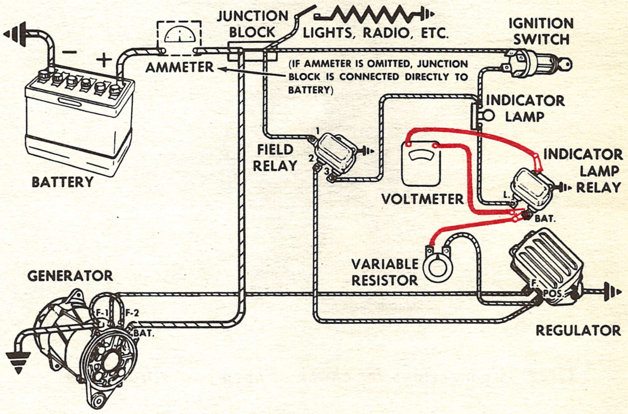
31-26. Check for open field discharge diode is shown at "A." Check for shorted back bias diode is shown at "B" and steps 1, 2, and 3 show the test for shorted power transistor.


JUNCTION BLOCK
LIGHTS, RADIO ETC.
IGNITION SWITCH
− +
AMMETER
(IF AMMETER IS OMITTED, JUNCTION BLOCK IS CONNECTED DIRECTLY TO BATTERY)
INDICATOR LAMP
BATTERY
FIELD RELAY
1
2
3
VOLTMETER
INDICATOR LAMP RELAY
L.
BAT.
VARIABLE RESISTOR
GENERATOR
F-1
F-2
BAT.
F.
POS.
REGULATOR

31-27. Instrument connections for checking closing and sealing voltage of field relay. (Delco-Remy.)


ARMATURE SPRING POST
(BEND TO ADJUST CLOSING VOLTAGE)

31-28. Adjusting closing voltage of field relay. Delco-Remy system.


JUNCTION BLOCK
LIGHTS, RADIO, ETC.
IGNITION SWITCH
− +
AMMETER
(IF AMMETER IS OMITTED, JUNCTION BLOCK IS CONNECTED DIRECTLY TO BATTERY)
INDICATOR LAMP
FIELD RELAY
1
2
3
BATTERY
VOLTMETER
INDICATOR LAMP RELAY
L.
BAT.
VARIABLE RESISTOR
GENERATOR
F-1
F-2
BAT.
F.
POS.
REGULATOR

31-29. Connections for checking closing voltage of indicator light relay Delco-Remy system.

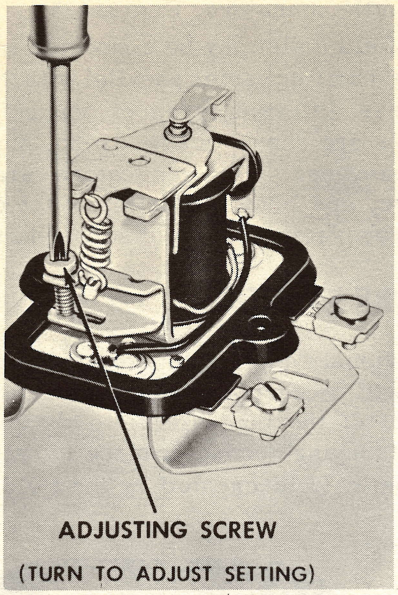
GENERATORS

Direct Current

As explained in the chapter covering alternating current generators, electrical pressure or voltage is generated when a conductor is moved through a magnetic field, or when a conductor is held stationary and the field is caused to move through the conductors. Voltage produced in this manner will cause current to flow when the circuit is completed.

It will be recalled, that rotating a coil of wire, Fig. 31-3, in a magnetic field would generate an alternating current. To use this alternating current, rectifiers were used which converted or rectified the alternating current to direct current.

A direct current generator, Fig. 31-31, operates in the same basic manner and first generates alternating current in a rotating coil or coils of wire (known as the armature) in a


ADJUSTING SCREW
(TURN TO ADJUST SETTING)

31-30. Method of adjusting relay closing voltage. Delco-Remy system.

magnetic field. But instead of a rectifier being used to convert the alternating current, a commutator is provided.

This commutator is used in place of the collector rings as shown in Fig. 31-32. To simplify the explanation, the illustration shows a simple armature with a single coil revolving in the magnetic field. As there is only a single coil in the armature, there are only two segments in the commutator which rotates with the coil. Each segment of the commutator is insulated from the other, and an end of the rotating coil is connected to each segment.

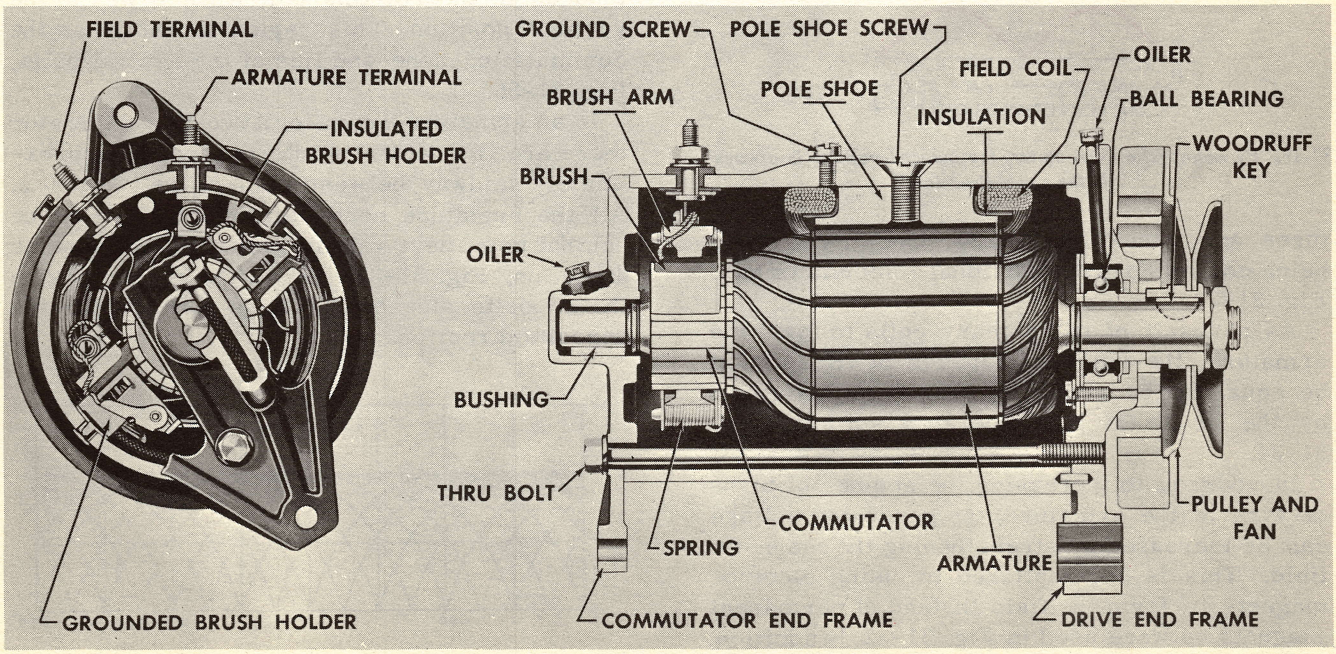
As the commutator revolves with the armature coil, first one segment of the commutator is connected to the right hand brush, then the other. The result is that one brush will always be positive and the other negative.

To describe this action in greater detail, as the armature coil approaches the position shown at A, Fig. 31-32, the voltage generated will approach a maximum, and the current will be leaving the left hand brush as shown, pass through the external circuit and return by way of the right hand brush. As the armature coil reaches the position shown at B, Fig. 31-32, the voltage will be zero. However, the rotating coil, with its commutator bar, is again about to cut through the magnetic field in the same direction as it did 180 deg. previously. The result is that current will again flow from the right-hand brush.

The commutator changes the alternating current generated within the armature to direct current as it leaves the brushes. In actual practice, armatures as used on automotive generators are provided with many coils and a commutator bar or segment for the end of each coil, Fig. 31-33.

PULSATING CURRENT

While the current will always flow in the same direction, as it leaves the brushes, it will rise


FIELD TERMINAL
ARMATURE TERMINAL
INSULATED BRUSH HOLDER
GROUNDED BRUSH HOLDER
GROUND SCREW
POLE SHOE SCREW
BRUSH ARM
POLE SHOE
FIELD COIL
OILER
BALL BEARING
INSULATION
WOODRUFF KEY
BRUSH
OILER
BUSHING
THRU BOLT
COMMUTATOR
SPRING
ARMATURE
PULLEY AND FAN
COMMUTATOR END FRAME
DRIVE END FRAME

31-31. Typical direct current shunt wound generator.

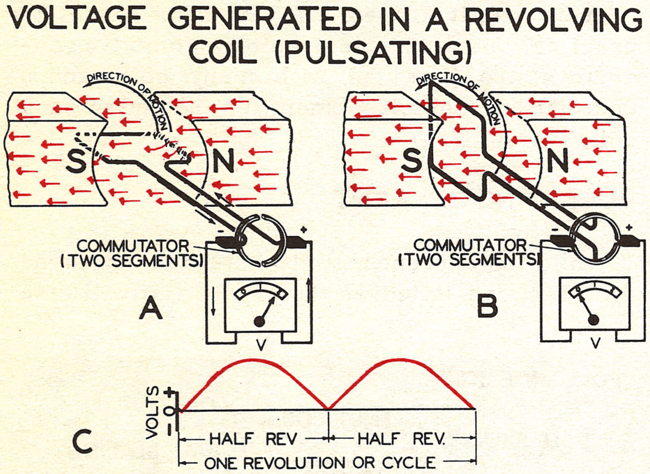
and fall in value. This is shown at C, Fig. 31-32, and is known as a pulsating current, resulting from the fact that the voltage will be maximum when the armature coil passes through magnetic field of maximum density, and drops to zero where the field is at zero density.

The strength of the voltage induced in the rotating coil is proportionate to the strength of the magnetic field, the speed with which the conductor or coil is moved through the field, and the number of turns of wire used to form the coil.

INCREASING THE VOLTAGE

In order to increase the voltage induced in the coil, the magnetic field is strengthened, the number of turns of wire in the coil is increased, and the speed of rotation of the coil is increased.

Also in order to eliminate the two peaks of current per revolution, Fig. 31-32, as is obtained with a single coil armature, generator armatures are wound with many coils, each coil being connected to its individual commutator bar, Fig. 31-33.


VOLTAGE GENERATED IN A REVOLVING COIL (PULSATING)
DIRECTION OF MOTION
S
N
COMMUTATOR (TWO SEGMENTS)
A
V
DIRECTION OF MOTION
S
N
COMMUTATOR (TWO SEGMENTS)
B
V
+
-
VOLTS
+
0
-
HALF REV
HALF REV.
ONE REVOLUTION OR CYCLE
C

31-32. By means of a commutator, the induced voltage is always in the same direction.

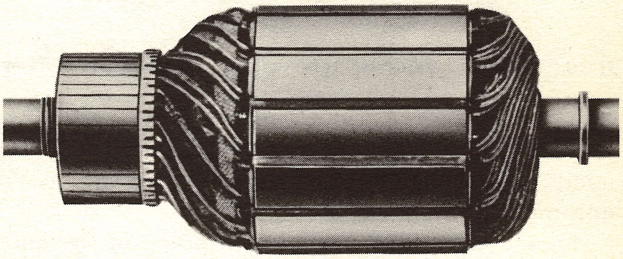
As a result of using many coils to form the armature, the number of peaks of voltage will be equal to the number of coils used, as shown by the graph of the generated voltage, Fig. 31-34.

In addition to increasing the number of turns of wire in the armature, the generated voltage can be increased by strengthening the magnetic field. This is accomplished by using electromagnets to form the field instead of permanent magnets as were used in Fig. 31-32. In addition, the number of field poles can also be increased. The electromagnets are supplied by current developed in the armature, Fig. 31-35.

These field coils may be connected in series, parallel (shunt) or series parallel with the armature. These different types of connections for generators are shown in Fig. 31-35. Most automotive passenger car generators are of the shunt type, and characteristics of the different types of generators will be discussed later.

ARMATURE REACTION

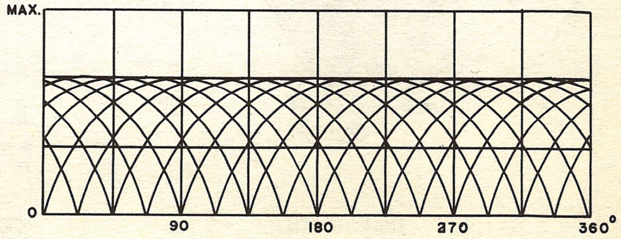
As previously explained, conductors carrying current will be surrounded by a magnetic field. The effect of the magnetic field created by the current-carrying conductor of the armature upon the magnetic field created by the field coils is known as armature reaction. This is an important consideration in the design and servicing of generators and motors.



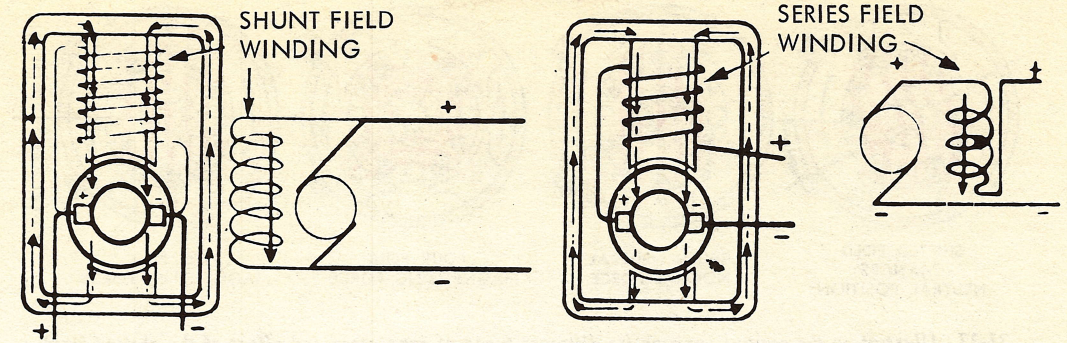
31-33. Typical automotive generator armature.

In Figs. 31-3 and 31-32 it was shown that in a generator with two field poles no voltage was induced in the rotating coil when it was in the vertical position. This region is known as the commutating zone and lies at the neutral point, Fig. 31-36.

In an armature wound for a two-pole generator there are two neutral points, one located approximately midway between each of the two poles. All the armature conductors on one side of the neutral point have voltage generated in the same direction, Fig. 31-37, and all the conductors on the opposite side have voltage generated in the opposite direction.

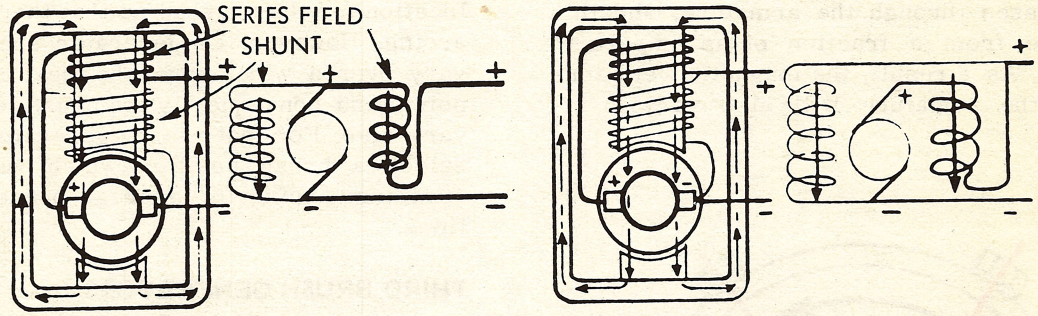


31-34. By using many coils in the armature, together with a commutator, a constant, direct voltage is produced.



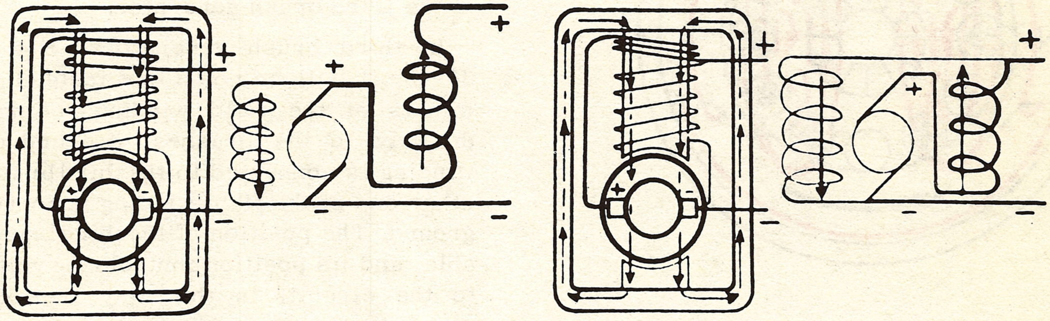
(1) Shunt wound dynamo.

(2) Series wound dynamo.



(3) Cumulative compound wound dynamo with short shunt.

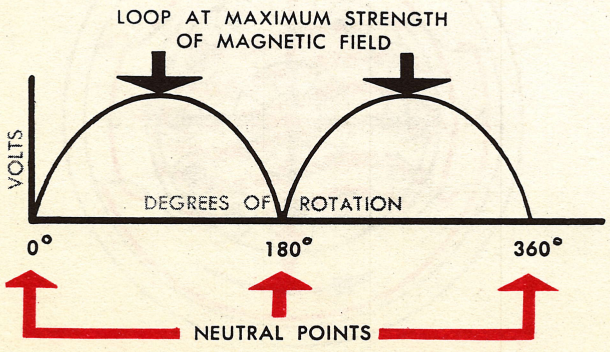
(4) Cumulative compound wound dynamo with long shunt.



(5) Differential compound wound dynamo with short shunt.

(6) Differential compound wound dynamo with long shunt.

31-35. Illustrating the different methods of connecting the field windings to the armature.

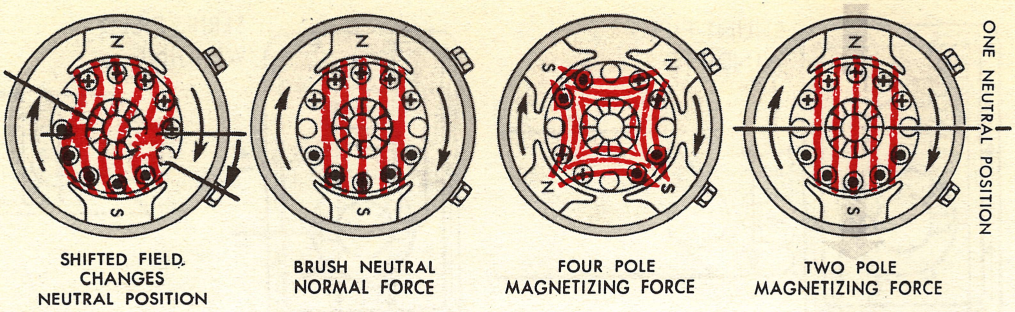


31-36. In an armature wound for a two pole generator, neutral points are located midway between the two poles.

Generators with more than two field poles have one neutral point for each field pole. For example, many automotive generators have four field poles and four neutral points, which are located between the field poles, Fig. 31-37.

However, the magnetic field set up by the armature will react on and distort the magnetic field set up by the field coils. As a result the neutral point will not be midway between the pole pieces, but will be shifted, and the direction of the shift will be in the direction of armature rotation.

In Fig. 31-38, the magnetizing force from the armature is shown. It must be remembered that


N
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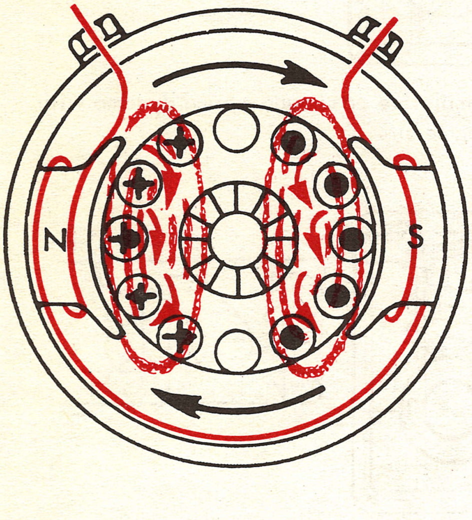
ONE NEUTRAL POSITION
SHIFTED FIELD CHANGES NEUTRAL POSITION
BRUSH NEUTRAL NORMAL FORCE
FOUR POLE MAGNETIZING FORCE
TWO POLE MAGNETIZING FORCE

31-37. Illustrating the neutral position for different types of generators and effect of the shifted field.

all the current flowing through the external circuit passes through the armature, and this may range from a fraction of an ampere to maximum. As a result, the magnetic field surrounding the armature will also vary in intensity.



31-38. Showing the magnetic field surrounding the coils of the armature when current flows through the coils.

The field resulting from the combination of the armature field and that produced by the field coils is shown in Fig. 31-39.

With a change in the field and a consequent shift of the netural position, a new location of the brushes becomes necessary. Otherwise, the armature coil being commutated would be generating voltage, and a high current would be short circuited between the commutator bars and the brush. This would cause a heavy arc to form, which would cause burning and rapid wear of the brush and commutator.

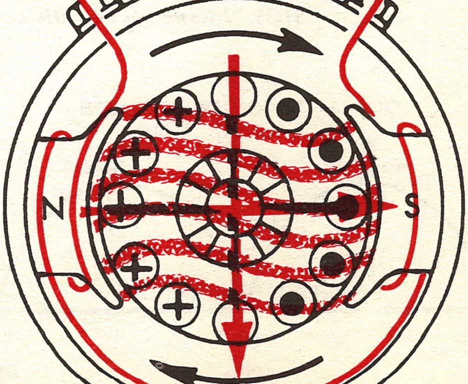
Fig. 31-40 shows the brushes shifted to the load neutral. Note that this new position is in the direction of armature rotation.

At a constant speed and load there is an ideal location for the brushes so that there will be no arcing. However, as generator speed and load vary over a wide range, the ideal commutating point (and consequently the brush location) will vary also. For that reason generator designers select a brush position which will give the minimum arcing for average operating conditions.

THIRD BRUSH GENERATORS

The reaction of the magnetic fields produced by the armature and the field can be used to control the output of the generator. This is done in the third brush generator.

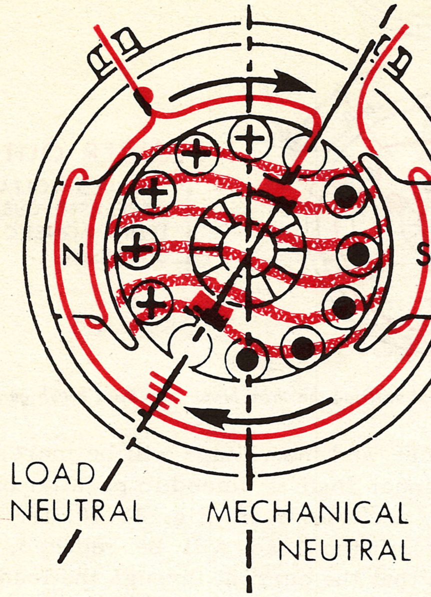
In third brush generators, Fig. 31-41 and 31-43, it will be noted that instead of both terminals of the field windings being connected directly to the brushes, one end of the field winding is connected to the third brush, while the other end of the field winding is connected to the ground. The position of the third brush is adjustable, and its position controls the voltage applied to the circuit. In this way the output of the generator can be controlled.



31-39. Showing the magnetic field formed after combining the fields of the armature and field coils.

The two main brushes, Fig. 31-42, are located at the neutral points on the commutator where there is maximum voltage, and as the third brush is positioned between the two main brushes it picks up less than the maximum available voltage.

Moving the third brush in the direction of armature rotation (toward the adjacent main brush) will increase the voltage across the field circuit, and the current through the field windings is thereby increased, Fig. 31-42.



31-40. Brushes have been shifted to the load neutral position.

Increasing the field current also increases the magnetic field strength, which in turn increases the output of the generator. Moving the third brush away from the adjacent main brush (against armature rotation) reduces the voltage across the field circuit, and results in lower generator output, Fig. 31-43.

It is also important to note that the voltage developed in the armature windings between the third brush and the ground brush, decreases as fewer magnetic lines of force are cut by the armature conductors when the lines of force shift from their neutral position, Fig. 31-42. This decrease in voltage forces less current through the field windings. As a result, the voltage across the main brushes is reduced, which in turn results in less pressure to cause current to flow through the load circuit.

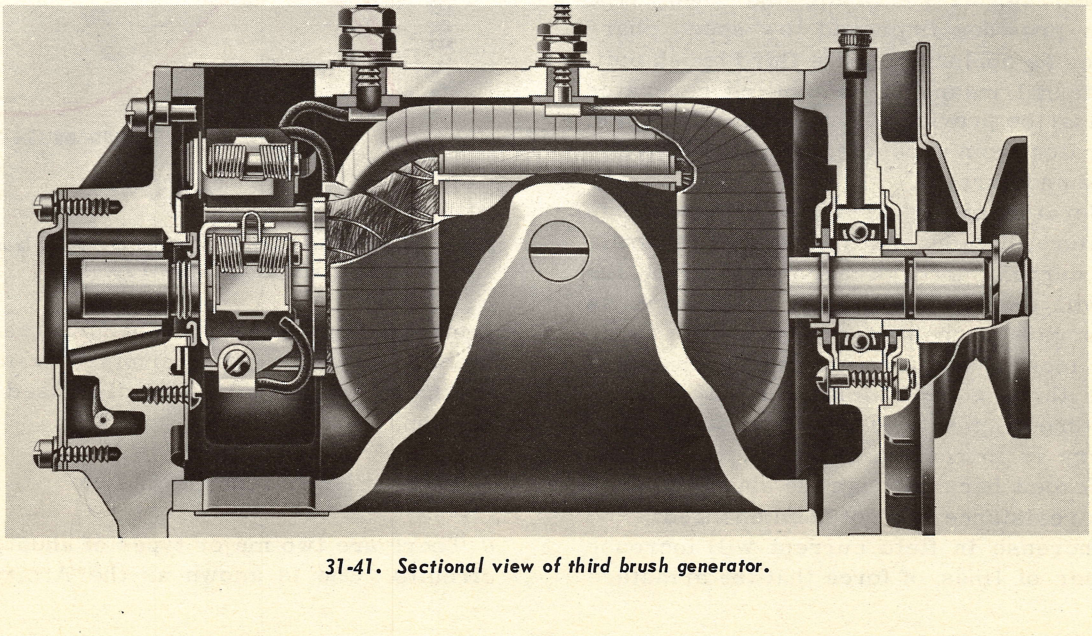
In that way, the third brush generator regulates its own current output without an external current regulator. However, some means of controlling the voltage is needed.

Fig. 31-44 illustrates the current output of shunt and third brush type generators. Note how the current provided by the third brush unit decreases as the speed goes up.

The third brush unit was used extensively on passenger cars up to 1939. At that time it was superseded by the shunt-type generator. However, the third-brush generator is still used extensively on farm tractors.

SHUNT WOUND GENERATORS

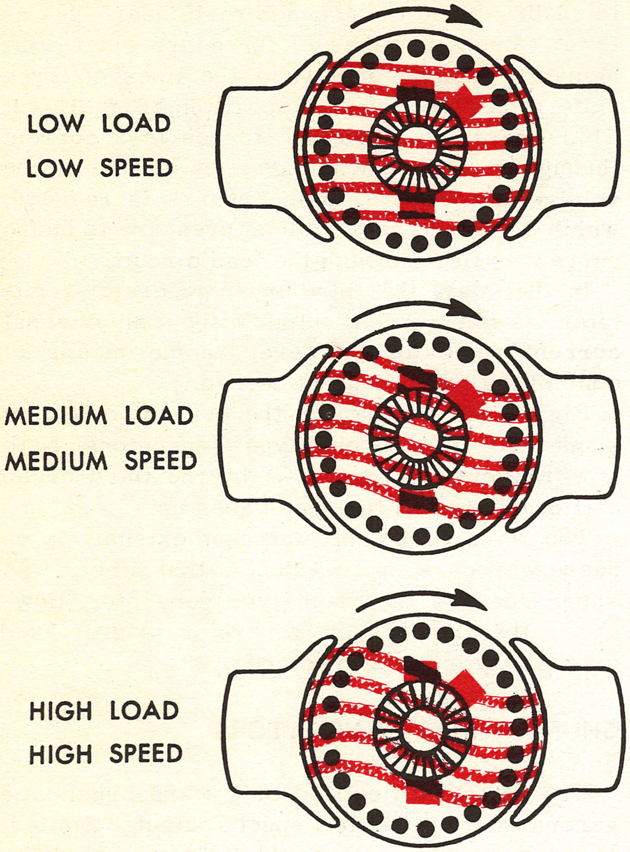
One of the difficulties of a third brush type generator is that at low speeds output is limited. In automotive operations this is a serious difficulty as at idling and low speed operation the starting battery would not be receiving a charge. In addition, there would be insufficient current



31-41. Sectional view of third brush generator.

for the operation of other electrical equipment.

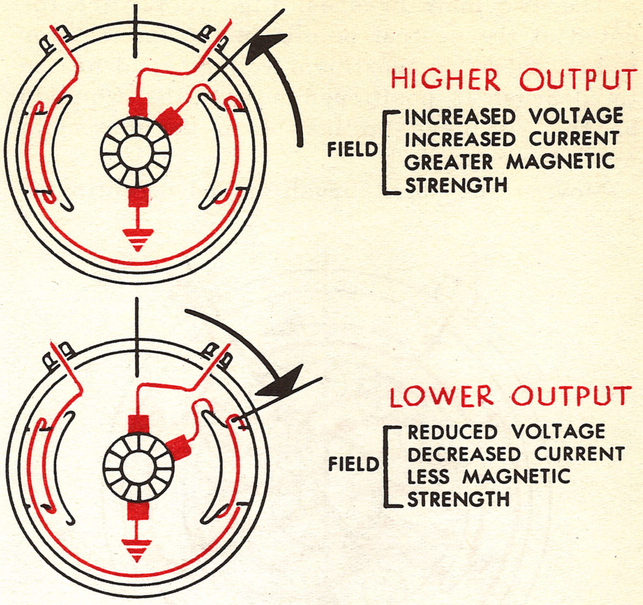
That is the main reason that the third brush generator was replaced by the shunt type generator.



31-42. Note how magnetic field shifts with rotational speed and load, on a third brush generator.

The shunt type generator has the field coils connected directly to the main brushes, Fig. 31-35 and Fig. 31-45. While the shunt type generator provides improved low speed characteristics as compared to the third brush unit, some external means of controlling generator output must be provided. Such controls prevent the generator from exceeding its rated capacity of voltage and current.

Consideration of Fig. 31-45, will show that as the armature, battery and field are all in parallel, the current through each branch of the circuit will then vary with their resistance. As the resistance of the battery is much less than the field, most of the current from the armature will pass through the battery, and only a small amount through the field. If the resistance of the battery is increased, more of the current will be forced back through the shunt field because its resistance has not been changed.

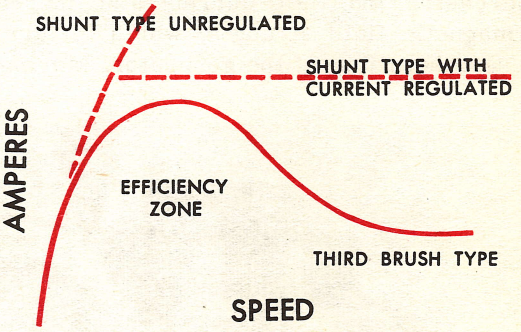


31-43. Effect of shifting the third brush of a third brush generator.

This increase in field current will increase the number of lines of force that the armature coils can cut, and the voltage will be increased.

If additional load is placed in parallel on the generator, as shown in Fig. 31-46, the total resistance of the load will be reduced, with the result that the current through the load will be still further increased and consequently the current through the generator field will be still further reduced. This in turn decreases the generated voltage.

As was previously pointed out, shunt wound generators are provided with current and voltage regulators which prevent current and voltage from exceeding predetermined values. Such means of regulation will be discussed in a later section.



31-44. Comparing the output of shunt and third brush type generators at different speeds.

SHUNT GENERATOR CIRCUITS

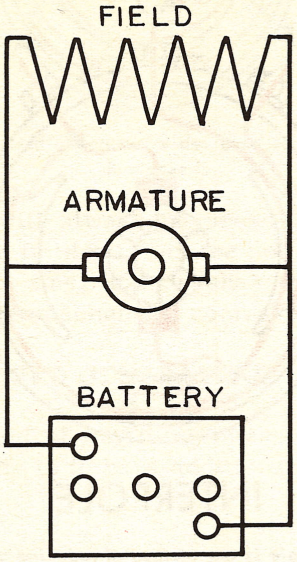
There are two major types of shunt generator circuits. One is known as the A circuit, Fig.

31-47, and the other is known as the B circuit, Fig. 31-48.

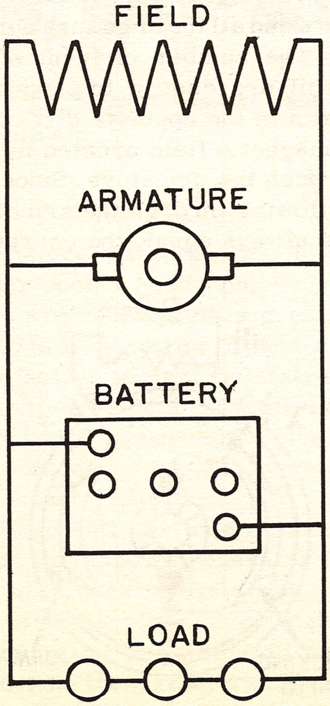
To understand the difference between these two generator circuits it is necessary to explain briefly the operation of the regulator which is used to control the output.

Regulators consist basically of spring-loaded contact points and a resistance. The contact points are opened electro-magnetically by means of a winding. When the points are open, the resistance is automatically connected to the field coils of the generator, thereby reducing the amount of current flowing in that circuit. This in turn reduces the strength of the magnetic field and lowers the output of the generator. When the points are closed, the resistance is shorted out of the circuit so the field current is increased and the generator output rises.

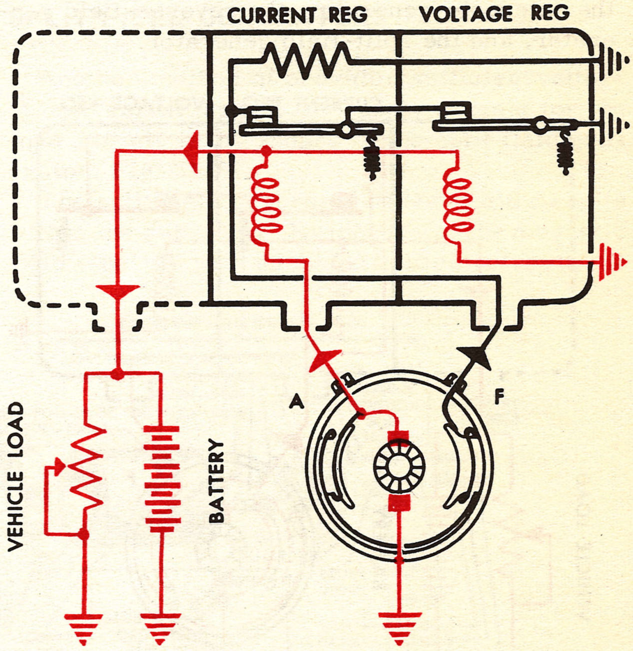
In the generator system shown in Fig. 31-47, the regulator resistance is inserted between the field and the ground, when the regulator points are open. This system is known as the A circuit or standard circuit.



31-45. With the armature, field and battery in parallel, the current through each branch of the circuit will vary with the resistance of each.



31-46. Placing additional load on the generator, reduces the resistance of the load.



31-47. In the "A" type generator circuit, the regulator resistance is inserted between the field and the ground when the regulator points are open.

In the B circuit (also known as the heavy duty circuit), shown in Fig. 31-48, the regulator inserts resistance between the insulated side of the circuit and the field coil.

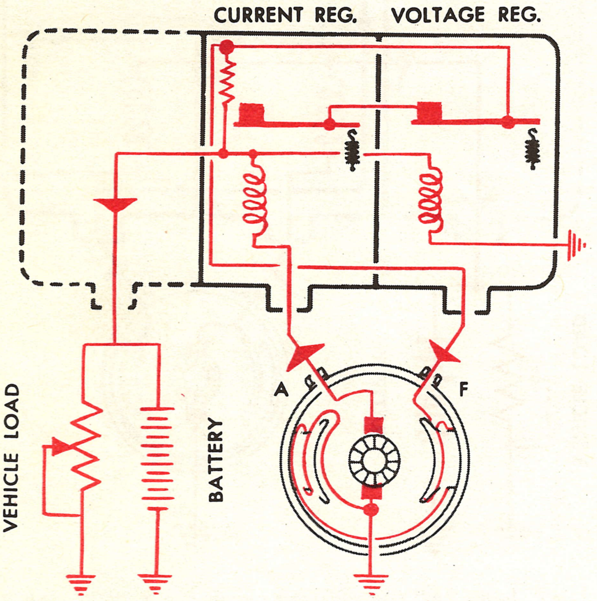
The A circuit is used primarily on Delco-Remy and Auto-Lite equipped passenger cars, whereas the B circuit is used on Ford built passenger cars. There is no particular advantage of using one circuit or the other.

SPECIAL GENERATOR CIRCUITS

As was previously pointed out, the magnetic fields set up by the field coils and the armature coils react on each other, strengthening the field at some points and weakening it at others. Furthermore, as the current through the armature and fields increases, there is a corresponding increase in the strength of the magnetic field, and also greater distortion and shifting of the field.

In most shunt-wound generators used in the automotive field, the shift in the magnetic field is not too great, and is compensated for by setting the brushes slightly ahead of the neutral position to obtain satisfactory commutation.

On certain generators, such as are used on some trucks or buses which have a heavy electrical load, the shift of the magnetic field is so great that some special means are required as compensation. These means are all variations of the basic shunt wound generator and include the interpole-generator, the reverse-field generator, and the split-field generator.

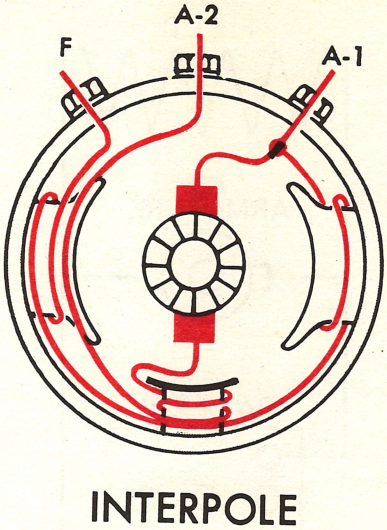


31-48. In the "B" type generator circuit, the regulator inserts resistance between the insulated side of the circuit and the field coil.

INTERPOLE GENERATORS

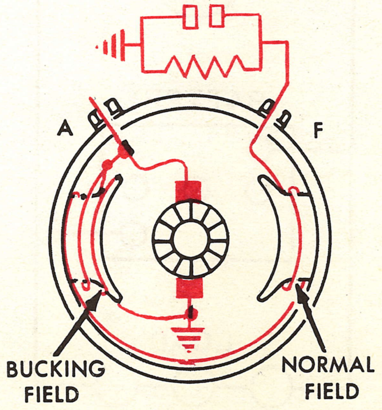
The mechanical neutral position of the magnetic field is midway between the field poles of the generator. At that point, the armature conductor, connected to the brushes through the commutator, will have zero current flow as the voltage at that point is changing from one direction to the other, Fig. 31-36. However, because the magnetic field has shifted from the neutral point, the armature conductor will still be generating voltage, and there is a flow of current when the conductor is shorted by the brushes.

It is therefore essential, if commutator arcing is to be reduced or eliminated, that the armature coil does not cut through lines of force during commutation. This can be accomplished by installing an "interpole," Fig. 31-49, which will tend to neutralize the magnetic field of the armature coils.

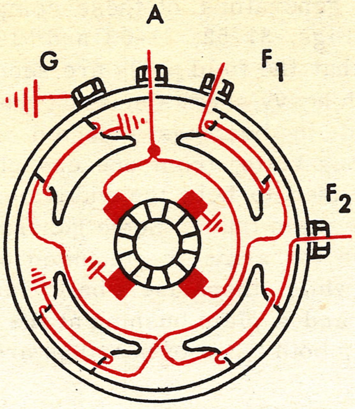


31-49. An interpole is one method of reducing arcing at the generator brushes.

This interpole is a narrow pole piece mounted on the generator frame between the two regular pole pieces, Fig. 31-49. It is wound with heavy bar copper since it is connected in series with the armature and all the armature current passes through it. The number of turns of wire in the interpole coil are chosen to produce sufficient ampere-turns in the opposite direction to counteract the magnetic field created by the current flowing through the armature. Since the amount of current flowing through the armature and the interpole is always equal, the correct amount of



31-50. A bucking field coil is wound in the reverse direction to the other field coils and controls the generated voltage.



31-51. A split field generator is designed to supply current at low speeds.

correction will always be present. As a result the magnetic field between the poles will remain in a straight line, and brushes will be located exactly on the mechanical neutral point.

BUCKING FIELD GENERATORS

One method of obtaining current at low generator speeds is to have additional turns of wire on the armature to obtain the higher voltage needed under such a condition.

However, when the speed is great, only a weak magnetic field is required to obtain the desired voltage. In fact, sufficient field strength will be provided by the residual magnetism of the field coils. But this voltage cannot be controlled. Even though the contact points of the voltage regulator open and insert resistance into the field coil circuit, voltage will continue to increase.

Voltage of this type of generator is controlled by means of a bucking field coil, Fig. 31-50. This is a shunt field coil of high resistance which is wound on one field coil and connected directly across the armature. The winding is connected in the reverse direction to the normal field winding, and its magnetic field opposes the normal field.

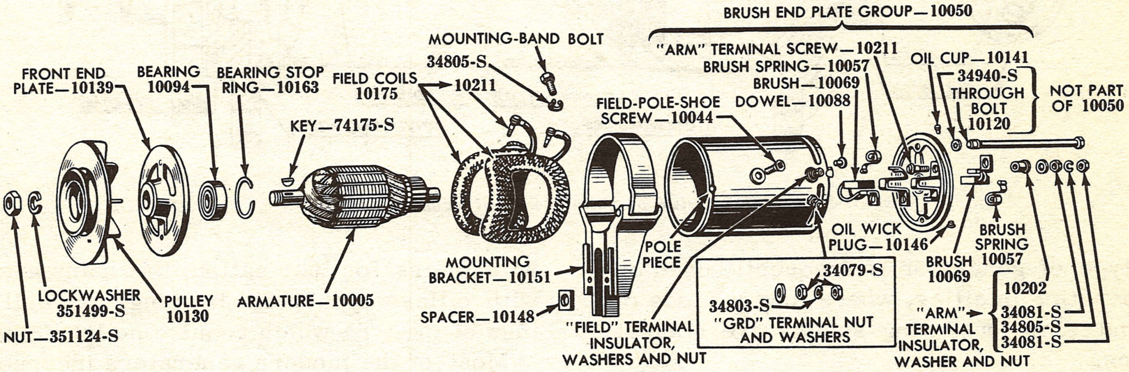
At low speeds, when normal field current is large, the opposing effect of the bucking field is not large in comparison to that of the main field. At higher generator speeds, when the current in the regular or main field circuit is reduced by the voltage regulator, the opposing effect of the bucking field is greater than the residual magnetic field, and practically all of the lines of force are cancelled. As a result the generated voltage will drop.

In that way, the current flow through the main field coils can be controlled by the regulator, and the effects of the residual magnetism can be controlled by the bucking field. Normal generator voltage will then be maintained.

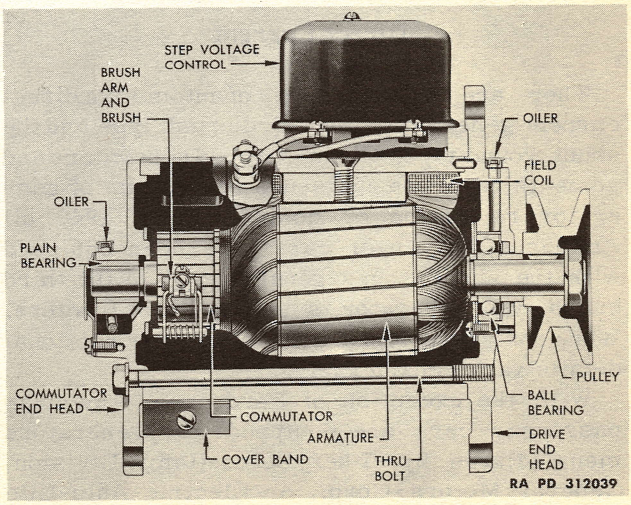
SPLIT FIELD GENERATORS

Another method of providing sufficient voltage at low engine speeds to supply current for the load circuit is by means of the split field generator, Fig. 31-51.

The split field generator has two field circuits within the generator. By increasing the magnetic field strength with an added field coil circuit, the


BRUSH END PLATE GROUP—10050
MOUNTING-BAND BOLT
34805-S
"ARM" TERMINAL SCREW—10211
BRUSH SPRING—10057
OIL CUP—10141
FRONT END PLATE—10139
BEARING 10094
BEARING STOP RING—10163
FIELD COILS 10175
10211
BRUSH—10069
34940-S
THROUGH BOLT 10120
NOT PART OF 10050
FIELD-POLE-SHOE SCREW—10044
DOWEL—10088
KEY—74175-S
OIL WICK PLUG—10146
BRUSH SPRING 10057
MOUNTING BRACKET—10151
POLE PIECE
34079-S
BRUSH 10069
10202
LOCKWASHER 351499-S
PULLEY 10130
ARMATURE—10005
34803-S
"GRD" TERMINAL NUT AND WASHERS
"ARM" TERMINAL INSULATOR, WASHER AND NUT
34081-S
34805-S
34081-S
SPACER—10148
"FIELD" TERMINAL INSULATOR, WASHERS AND NUT
NUT—351124-S

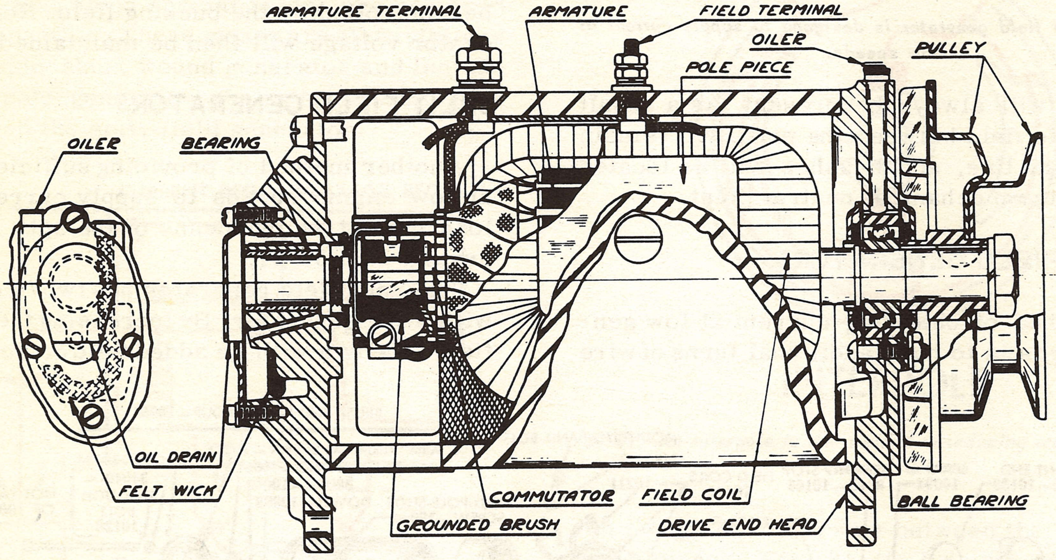
31-52. Recent model Ford generator of the shunt type.


STEP VOLTAGE CONTROL
BRUSH ARM AND BRUSH
OILER
FIELD COIL
OILER
PLAIN BEARING
PULLEY
COMMUTATOR END HEAD
BALL BEARING
COMMUTATOR
ARMATURE
DRIVE END HEAD
COVER BAND
THRU BOLT
RA PD 312039

31-53. Delco-Remy third brush type generator with regulator.

voltage necessary to provide current for the load circuit can be reached at a much lower speed.

The stronger field necessary for developing voltage at low speeds is accomplished by splitting the field circuit into two separate circuits, each controlled by its own voltage and current regulator. Each set of field coils is designed for maximum allowable field coil current. The split field generator has approximately twice the field strength of a generator having only one field coil.



31-54. Sectional view of Auto-Lite shunt-wound generator.

This type of generator is frequently used on buses operating in cities, where long periods of idling and slow operating speeds are normal conditions.

GENERATOR CONSTRUCTION

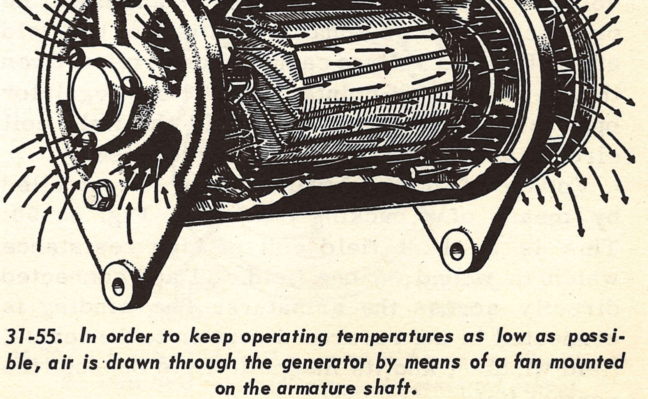
Direct Current

There are two main types of automotive direct current generators, the third brush type and the shunt wound type. All shunt wound generators and some third brush units use some form of generator regulation or control. Since 1940 all American passenger cars have been equipped with the shunt wound generator while the third brush type generator is used on farm tractors. While only two types are in use constructional details vary considerably.

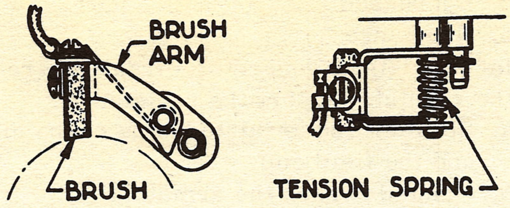
With the exception of Ford cars, American passenger cars are equipped with generators manufactured by either Delco-Remy Division, General Motors Corp., or Electric Auto-Lite Co.

Typical generators of these companies are shown in Figs. 31-52, 31-53 and 31-54. It will be noted that the field poles are secured to the frame with heavy screws and that the armature is carried in bearings mounted in the end plates. Long bolts, from one end plate to the other are used to hold the end plates securely against the main frame. Some generator armatures, have the armature mounted on two ball bearings, while others use a ball bearing at the drive end and a plain bushing at the other end. In general, both types of bearings are provided with oilers for lubrication. But many are fitted with oilless type plain bushings and ball bearings of the type which require no lubrication.

Most of the modern generators incorporate a cooling fan, Fig. 31-55, in their design which usually forms part of the driving pulley. Cooling is required because as generator temperatures



31-55. In order to keep operating temperatures as low as possible, air is drawn through the generator by means of a fan mounted on the armature shaft.



31-56. Two types of brush holders; the swivel type is shown on the left, and the box type on the right.

increase, they will generate less current.

Several different types of commutator brush holders are used; reaction, swivel and box being the main types, Fig. 31-56.

The diameter of automotive generators is the same within narrow limits. However, the length is increased as greater capacity is desired. The greater length permitting longer field coils and armatures. In addition, a longer commutator gives longer brush life and commutator life.

On some types of direct current generators, the field frame is provided with openings at the brush end of the unit so the brushes and commutator can be more easily inspected. These openings are then covered with a removable steel strap or cover band, to exclude dirt. On most generators, these ports or openings are not provided, making it necessary to remove the generator for inspection, sanding of the commutator, and installation of brushes.

QUIZ - ELECTRIC GENERATORS

1-For what purpose is the automotive generator used?

2-What happens when a coil of wire is moved through a magnetic field?

3-When rotating a coil of wire through a horizontal magnetic field, maximum voltage will be produced in what position of the coil?
  a. Horizontal
  b. Vertical

4-In most alternators, the voltage is generated in which part of the unit?
  a. Rotor
  b. Stator

5-In most alternators what is the name of the part which supplies the field?

6-In an alternator, what is the name of the part which changes the current from alternating to direct?
  a. Converter
  b. Commutator
  c. Rectifier

7-What kind of current is supplied to the field of an alternator?
  a. Direct
  b. Alternating

8-For what purpose is a diode used on a modern automotive alternator?

9-What is a major advantage of an alternator over a direct current generator for automotive service?

10-How many windings are there in a Y-type stator?
  a. One
  b. Two
  c. Three
  d. Five

11-When checking for a grounded stator, one prod of the test lamp is touched to the frame and the other to each of the stator leads in turn. If the lamp lights, what is indicated?
  a. A ground
  b. A short circuit
  c. An open circuit
  d. Circuit is in good condition

12-What instrument is used to check Delco silicon diode rectifiers?
  a. Ammeter
  b. Voltmeter
  c. Ohmmeter
  d. Oscilloscope

13-On the Delco regulator as used with their alternator how is the voltage setting adjusted?
  a. Adjusting spring tension
  b. Adjusting screw in base of regulator
  c. Adjusting thermostat

14-In a direct current generator, voltage is generated in which unit?
  a. Armature
  b. Field
  c. Stator
  d. Regulator

15-In a direct current generator, what device is used to change alternating current to direct?
  a. Commutator
  b. Rectifier
  c. Transistor

16-What three methods can be used to increase the strength of the generated voltage?

17-What is armature reaction?

18-In an armature wound for a two pole generator, how many neutral points are there?
  a. Two
  b. Four

c. Six

19-Does the current output of a third-brush generator increase or decrease with the speed of rotation?
   a. Increase
   b. Decrease

20-Which type of generator has the better low speed characteristics?
   a. Shunt
   b. Third brush

21-In the A-type generator circuit, where is the regulator resistance inserted?
   a. Between the field and the ground
   b. Between the insulated side of the circuit and the field coil
   c. Shunted across the armature

22-When the third brush is moved in the direction of armature rotation is output increased or decreased?
   a. Increased
   b. Decreased
   c. No change

23-In the B-type generator circuit where does the regulator insert the resistance?
   a. Between the insulated side of the circuit and the field coil
   b. Shunted across the armature
   c. Shunted across the field

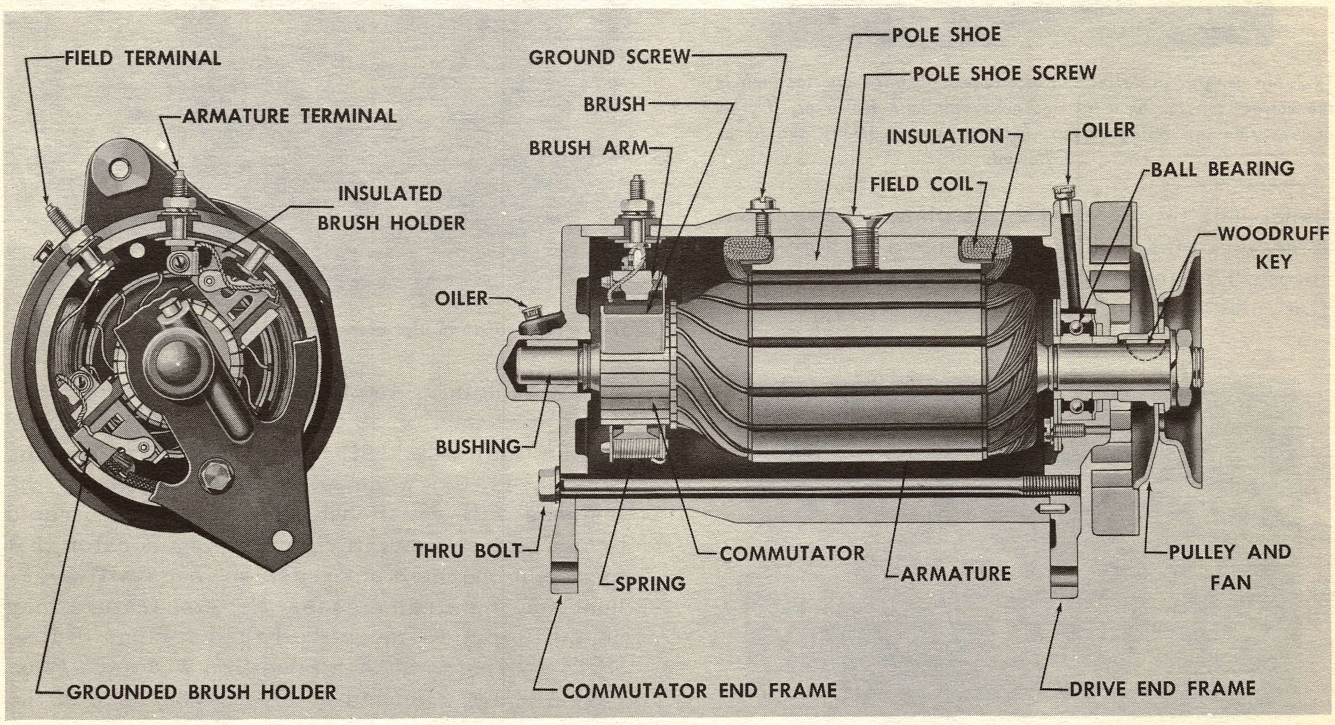
24-What is the purpose of an interpole in a generator?
   a. Increase output
   b. Decrease arcing at the brushes
   c. Maintain constant voltage

25-What is the purpose of a bucking field generator?
   a. Control the voltage
   b. Increase the output
   c. Strengthen the magnetic field

26-Why are cooling fans incorporated in the design of modern automotive generators?

GENERATOR SERVICING AND TESTING

To obtain maximum life from a generator it is important that regular inspection and maintenance procedure be followed. Periodic lubrication, where required; inspection of brushes and commutator and checking of brush spring tension are essential. In addition, it is important that electrical connections be checked.


FIELD TERMINAL
ARMATURE TERMINAL
INSULATED BRUSH HOLDER
GROUNDED BRUSH HOLDER
GROUND SCREW
BRUSH
BRUSH ARM
OILER
BUSHING
THRU BOLT
SPRING
COMMUTATOR
COMMUTATOR END FRAME
POLE SHOE
POLE SHOE SCREW
INSULATION
FIELD COIL
ARMATURE
OILER
BALL BEARING
WOODRUFF KEY
PULLEY AND FAN
DRIVE END FRAME

32-1. Typical Delco-Remy shunt wound generator.

LUBRICATION

Generator bearings fitted with hinge cap type oilers, Fig. 32-1, should receive from 8 to 10 drops of light engine oil every 5000 miles. More than that may cause oil to get on the commutator and brushes causing arcing. In addition, excess oil will tend to rot electrical insulation.

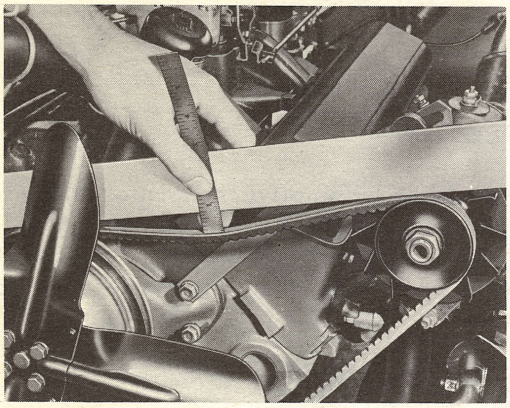
INSPECTION

In general automotive generators should be checked and inspected every 10,000 miles. However, if the car is operated in areas where there is excessive dust, at high speeds, or if most of the operation is at high electrical load, the inspection should be at more frequent intervals.

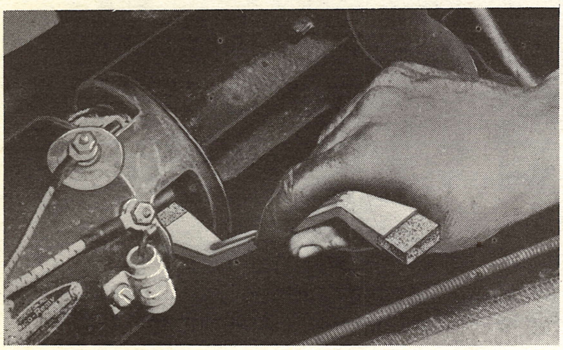
The first step in the generator inspection is to make sure that all the electrical connections are tight and making good electrical contact. Also make sure the drive pulley is tight on the shaft and the mounting bolts are tight. The generator drive belt should be checked to make sure that it is in good condition and is adjusted to the proper tension, Fig. 32-2.

COMMUTATOR SERVICING

Remove the cover band if the generator is so equipped and inspect the commutator, brushes and electrical connections. If the commutator is dirty or rough, it may be sanded with No. 00 sandpaper or special tool as shown in Fig. 32-3. Emery cloth should never be used on a commutator. To sand a commutator, wrap the end of a flat piece of soft wood with a strip of No. 00 sandpaper, and with the generator in operation hold the sandpaper against the commutator. Move the sandpaper back and forth so the entire area of the commutator is sanded. Sandpaper in rolls designed especially for sanding commutators can be secured from automotive parts jobbers.



32-2. *In general, a deflection of one-half to three-quarter inch is the correct tension on a fan and generator belt. However, if other accessories are being driven, factory specifications should be followed.*

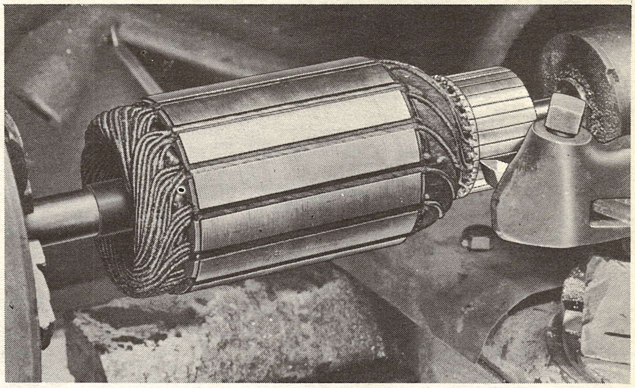


32-3. *Dressing a commutator with a special tool.*

If the commutator is rough and pitted, the generator should be disassembled, and the commutator turned down on a lathe, Fig. 32-4. In addition the mica, Fig. 32-5, should be under cut so that it is 1/32 in. below the surface of the commutator bars.

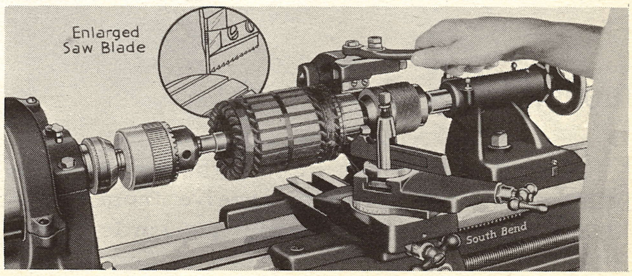
BRUSH REPLACEMENT

After inspecting and sanding the commutator, the interior of the generator should be blown clean with compressed air. If the brushes are worn down to one-half their original length they should be replaced. The amount of wear can be determined by comparison with a new brush. Make sure the new brushes are free in the brush holders. New brushes should be sanded so they conform to the curvature of the armature. This is accomplished by placing a strip of No. 00 sandpaper between the armature and the brush. Then with light pressure on the brush the sandpaper is withdrawn.

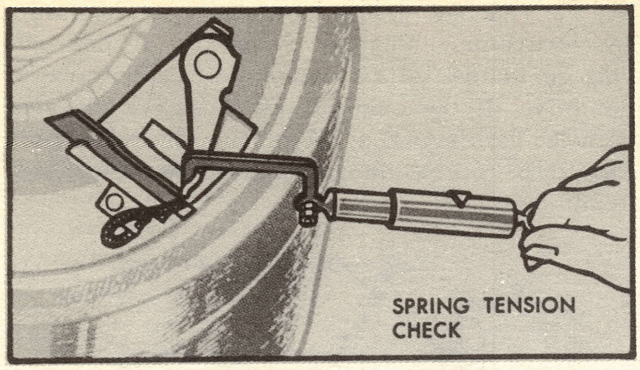


32-4. *Turning down the commutator of an armature on a lathe.*

The tension of the brush spring is important, for if the tension is too great, rapid brush and commutator wear will result. If the brush spring tension is too weak, Fig. 32-6, arcing at the brushes will result, which in turn causes rapid brush and commutator wear. A generator that has been operated at excessive loads will overheat and in extreme cases the temperature may be sufficient to cause the brush springs to lose their strength. Such a condition will usually be revealed by a burned or blue appearance of the



32-5. *Undercutting the mica on a commutator with a special attachment on a lathe.*



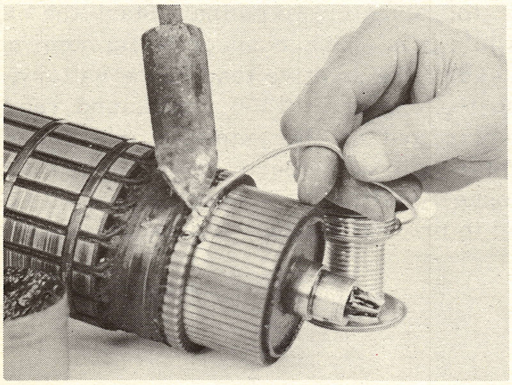
32-6. Checking the tension of a brush spring with a spring scale.

spring. Such springs should be replaced.

Inspect the inner surface of the generator cover band for tiny globules of solder. If any solder is found, it is an indication that the generator was producing excessive current and the solder used in connecting the armature wires to the commutator bars has melted. In such cases, the armature should be replaced or the connections resoldered, Fig. 32-7. Electrical tests for the armature will be explained in another section.

THIRD BRUSH OUTPUT

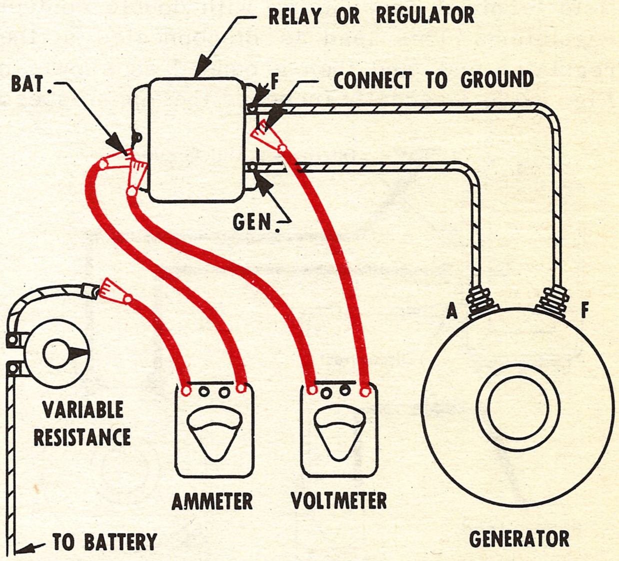
An ammeter, voltmeter, and variable resistance are used to check the output of the third brush type generator. The ammeter and variable resistance are connected in series into the charging circuit at the relay or regulator "BAT" terminal and the voltmeter between that same terminal and the ground as shown in Fig. 32-8. If the generator is equipped with a regulator, the "F" terminal must be grounded temporarily with a jumper lead to eliminate the action of the regulator while the test is being made.



32-7. Soldering armature coils to commutator bars.

With the generator at operating temperature increase the generator speed to the value given in the manufacturer's test specifications, adjust the variable resistance to obtain the specified voltage and note the current indicated on the ammeter. If the generator is checked with a fully charged battery in the circuit the variable resistance may not be required. But if the battery is not fully charged (as is usually the case) the variable resistance will be needed in order to increase the voltage to the specified value.

When checking a generator with a manually or thermostatically controlled field resistance, make sure the field resistance is shorted out of the field circuit before attempting to adjust the generator output.



***32-8.** Meter connections for checking output of third brush generator. If generator is equipped with a regulator, the "F" terminal must be grounded while making the test.*

On many third brush generator models fitted with voltage regulators, the position of the third brush is not adjustable. When the third brush is adjustable, the output is increased by moving the brush in the direction of armature rotation. The usual construction of the third brush permits adjustment after loosening one or more clamping screws. Some models have the clamping screw accessible on the outside while other designs have the clamping screw on the inside of the commutator end frame.

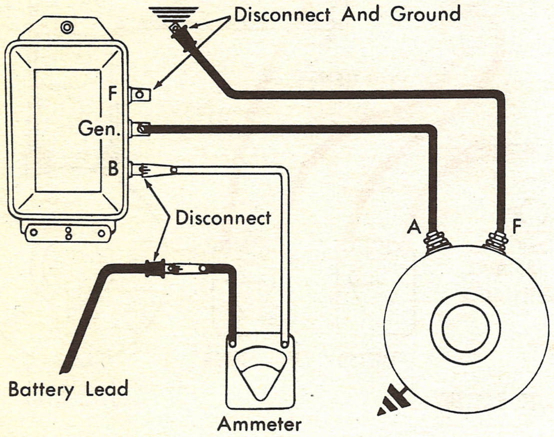
Third brush generators must never be operated on open circuit as this would result in burning out the generator, as previously explained. Neither should they be adjusted above the specified maximum output.

SHUNT GENERATOR OUTPUT "A" CIRCUIT

Caution: On all cars with double contact regulators, NEVER GROUND the generator field with the regulator connected to the generator. This will instantly burn the upper set of contact points on the regulator. Double contact regulators are usually found on cars equipped with air conditioning and other electrical equipment which imposes a heavy load on the generator.

CURRENT OUTPUT TEST

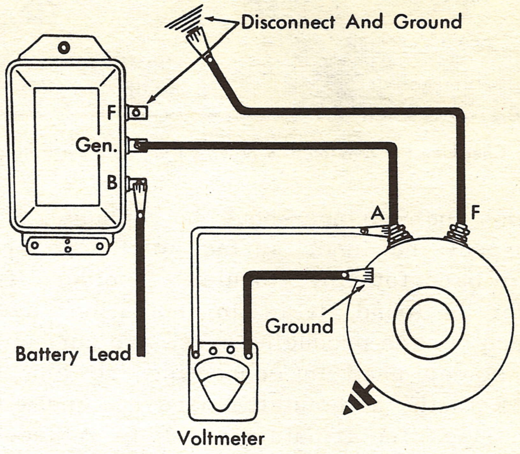
Connect an ammeter as shown in Fig. 32-9, making sure to disconnect the lead from the field terminal on systems with double contact regulators. This lead is disconnected at the regulator end, and then grounded as shown in Fig. 32-9. Gradually increase the engine speed until the ammeter indicates at least 25 per cent above the rated output of the generator. If the output does not reach that value and increase steadily, it should be checked further to determine the cause of the low output.



32-9. Method of making generator output test.

VOLTAGE OUTPUT TEST

Such a test should be made to determine that all the windings in the armature are still operating, and the insulation of the generator windings are in good condition. Connect a voltmeter as shown in Fig. 32-10. Make sure all lights and accessories on the vehicle are turned off. Speed up the engine until the voltmeter indicates in excess of 16 v. on 12 v. systems and 8 v. on 6 v. systems. This should not require a very high engine speed. Do not operate the engine at that speed for more than a second or two as that would damage the generator. If those voltages are not reached, disconnect wire from regulator to generator armature terminal. If correct voltage is then attained, the starting battery is defective. If the correct voltage is not attained with the battery out of the circuit, the generator should be overhauled, checking the fields and armature.

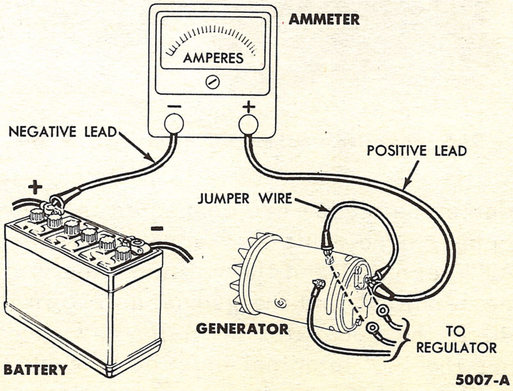


32-10. Checking voltage output of shunt generator.

SHUNT GENERATOR OUTPUT "B" CIRCUIT

Disconnect the regulator armature and field wires at the generator. Connect a jumper wire from the generator armature terminal to the generator field terminal, Fig. 32-11, also the positive lead of a 0-50 ampere ammeter to the generator armature terminal. Start the engine and while it is idling, connect the ammeter negative lead to the positive lead of the battery.

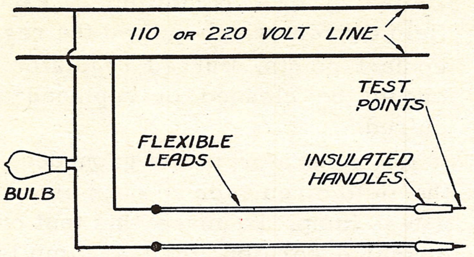
Run the engine at 1500 r.p.m. and read the current output on the ammeter. The generator should reach or exceed its specified output. Disconnect test leads as soon as the test is completed to prevent overheating the generator.



32-11. Connections for checking output of "B" circuit generators.

TESTING FOR GROUNDED FIELD

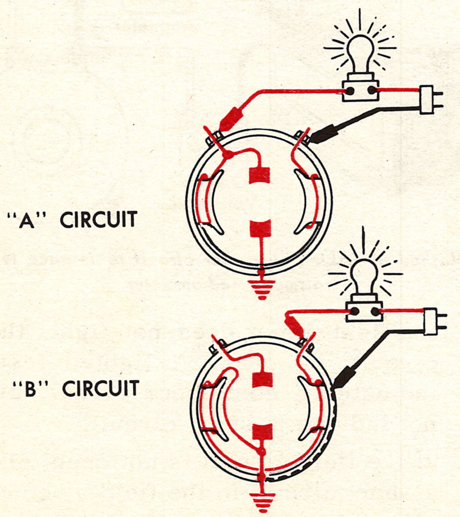
A test lamp, Fig. 32-12, is used to determine if the field circuit is grounded. All intended field coil connections must be disconnected. On A circuit generators, raise both brushes. On B circuit generators raise both brushes and also disconnect field from grounded brush. Place one test point on generator frame and other on field terminal. If lamp lights, field is grounded. If it does not light, there is no ground. A short circuited field coil will have little effect on generator output.



32-12. The test leads as shown above can be used for making many electrical tests for continuity and open circuits.

CHECK FOR OPEN CIRCUITS OR SHORTS

If no ground is indicated, check field coils with test light for open circuit. This can be done by placing test points on ends of field coil leads in turn, Fig. 32-13. If test lamp does not light an open circuit is indicated. A short in a field coil is most easily detected by comparing the current draw of the field coil with the value listed in the specifications of that particular generator. To do this, connect the field coil in series with a battery (6 or 12 v. in accordance with the particular generator) and an ammeter. If the current indicated by the test is higher than the specified value, a short is present, and new field coils should be installed.

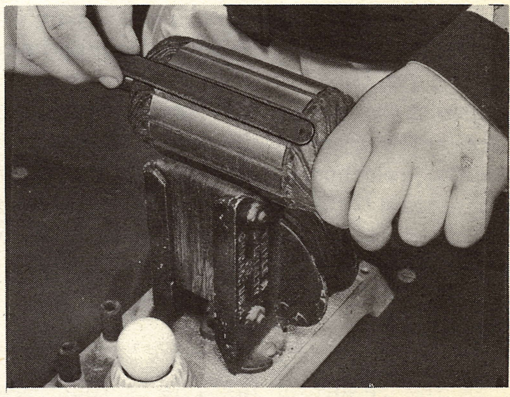


32-13. Testing "A" and "B" circuit generator fields with test lamp. If the lamp does not light the circuit is open. A lighted test lamp indicates a continuous circuit, but does not indicate a shorted circuit.

TESTING THE ARMATURE

The armature is tested for shorts by placing in a growler, Fig. 32-14. A short circuit will cause a short strip of steel to vibrate when it is held over the armature core. While making the test, the armature is rotated slowly in the jaws of the growler in order to check all of the coils of the armature.

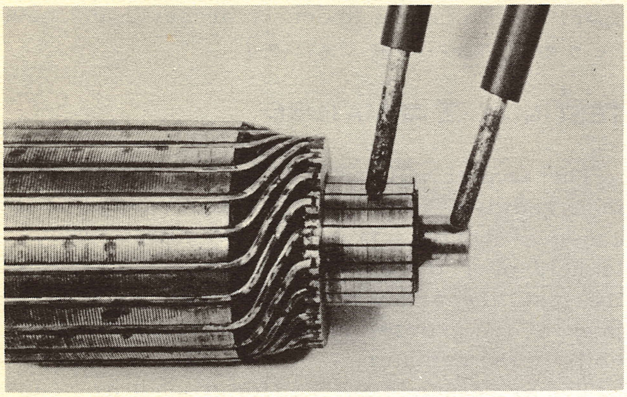
The armature is checked for grounds by means of a test lamp, Fig. 32-12. The procedure is to touch the armature shaft with one point of the test set and any one of the commutator bars with the other point, Fig. 32-15. The armature should be replaced if a ground is indicated by the lamp lighting.



32-14. Checking an armature for a short circuit by means of a growler.

GENERATOR CIRCUIT RESISTANCE TEST

Excessive resistance in the charging circuit will cut down current to the battery, or increase generator voltage. The check for the insulated side of the charging circuit is as follows: Connect the ammeter and voltmeter as shown in Fig. 32-16. The generator field control is a 25 ohm, 25 watt unit with an open position. Start the engine and operate at fast idle. Adjust the generator field control knob until the generator charges at 20 amp. If necessary, turn on some lights in order to obtain that value. The voltmeter should not read more than 0.8 volts. If voltage exceeds that amount there is excessive resistance in the circuit. Voltage drop from armature terminal,of generator to armature terminal of regulator should not exceed 0.2 volts; from armature terminal of regulator to battery terminal of regulator 0.2 volts; across test ammeter and leads 0.25 volts; from end of disconnected battery wire to ungrounded post of battery 0.15 volts.



32-15. Using a test lamp and prods to test armature coils for grounds.

To check the generator circuit resistance of the generator ground circuit, connect the instruments as shown in Fig. 32-17. With the engine at fast idle, adjust the generator field control knob to obtain a charging rate of 20 ampere. The voltage should not exceed 0.1 volt.

NO OUTPUT

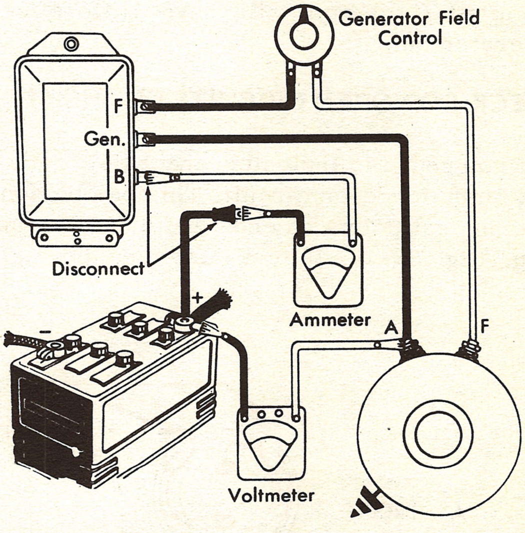
If, as the result of tests it is found that no current is being generated, remove the cover band (if so equipped) and check the brushes, commutator and internal connections. Also examine the inner surface of the cover band. If it is speckled with dots of solder, it indicates that the generator was overloaded to such an extent, that the solder at the commutator bar risers has been melted. This in turn results in open circuits in the armature windings.

If the brushes are satisfactorily seated and are making good contact with the commutator and the trouble is not apparent, it will be necessary to use a test lamp, Fig. 32-12, to locate the trouble. The procedure is as follows:

1. First disconnect the leads from the generator terminals. Insert a piece of paper or other insulation between the grounded brush and the commutator. Check for grounds with the test lamp, between the generator main brush or A terminal and the generator frame. If the generator is of the type that is internally grounded to the frame, disconnect the field ground lead before making this test. If the lamp lights, it indicates that the generator is internally grounded. The location of the ground can be found by raising and insulating all the brushes from the commutator and checking the brush holders, armature, commutator and fields separately.

   If a grounded field is found, check the regulator contact points since a grounded field may have permitted an excessive field current which burned the regulator contact points. Burned regulator points should be cleaned or replaced as required.
2. If the generator is not grounded, check the field circuit for an open circuit with a test lamp. To make this test on an A circuit generator, the test lamp is connected to the armature and field terminals of the generator. On B circuit generators, the test lamp is connected to the field terminal and the ground. If the test lamp does not light, the field circuit is open. A lighted test lamp indicates a continuous circuit, but does not indicate a short circuit.
3. If the field circuit is not open, check for a short circuit in the field by connecting a battery of the specified voltage and an ammeter in series with the field circuit. If the current flowing is not in accordance with the value given in the specifications, new field coils should be installed.

   If a shorted field coil is found, the regulator contacts should be checked, as a shorted field may have permitted ex-



32-16. Method of making generator circuit resistance test, using voltmeter and ammeter.

cessive field current which would cause the regulator contacts to burn.

4. If the preceding tests have not located the trouble, the armature should be checked next. Open circuits in armatures are usually obvious as open circuited commutator bars will arc each time they pass under the brushes, so that the bars will soon be badly burned and pitted. It is usually advisable to replace the armature. However, if the commutator bars are not badly burned, and the "open" in the armature is at the point where it is soldered to the commutator bar, the repairs can be easily made, Fig. 32-7. If any doubt exists, the armature can be tested for open circuit as previously described using a test lamp.

Short circuits in armatures are located by means of a growler as previously described.

LOW OR UNSTEADY OUTPUT

If a low or unsteady output is produced by the generator, the following checks and tests should be made.

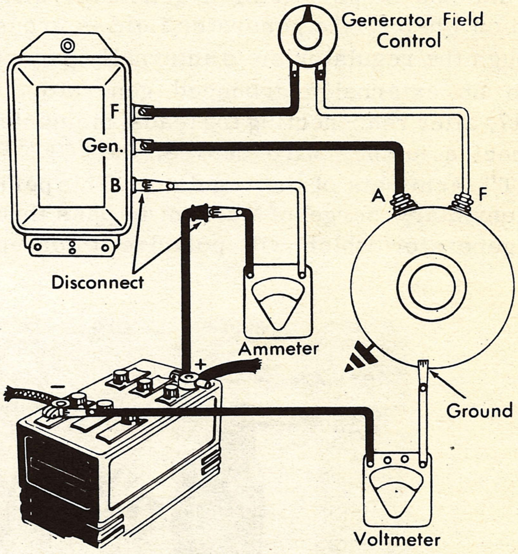
1. A loose generator drive belt will slip and cause a low or unsteady generator output.
2. Sticking brushes, or low brush spring tension will prevent good contact with the commutator so that the output will be low or unsteady. This will usually be accompanied by arcing at the brushes.
3. Dirty, out-of-round, or high mica commutators will frequently result in low or unsteady output. The remedy is to turn the commutator in a lathe and undercut the mica.

EXCESSIVE GENERATOR OUTPUT

When tests show that the generator output is excessive, (as shown in the section devoted to current and voltage regulators) even after the "F" terminal has been disconnected, the trouble will be in the generator itself. The procedure to be followed in locating the trouble will depend on the type of generator-regulator circuit the system uses.

There are two basic circuits. These differ essentially in the part of the circuit in which the regulator inserts resistance. In one circuit the generator field circuit is grounded through the regulators, Fig. 31-47, while in the other circuit the generator field is grounded internally, Fig. 31-48.

In the circuit which is grounded through the regulator, an accidental internal ground in the field circuit would prevent correct regulation so that excessive generator output may result. On that type of circuit an internally grounded field circuit which would cause excessive output may be located by means of a test lamp by connecting it between the "F" terminal and the generator frame. When making this test, the leads should be disconnected from the "F" terminal and the brush to which the field lead is connected inside the generator should be raised from the commutator. If the test lamp lights, the field is internally grounded. Such a ground frequently results from the insulation on the field lead being worn away, and can easily be repaired by taping the lead. It is also possible to make a repair when the ground has occurred at the pole shoes. To make such a repair, remove the field coils and after reinsulating them, they can be reinstalled.



32-17. Generator circuit ground test.

If the generator is of the type which has the field circuit internally grounded, Fig. 31-48, the only cause for excessive output (with the lead disconnected from the "F" terminal) would be a short between the field circuit and the insulated main circuit. To repair such a condition, it is only necessary to reinsulate and relocate the leads.

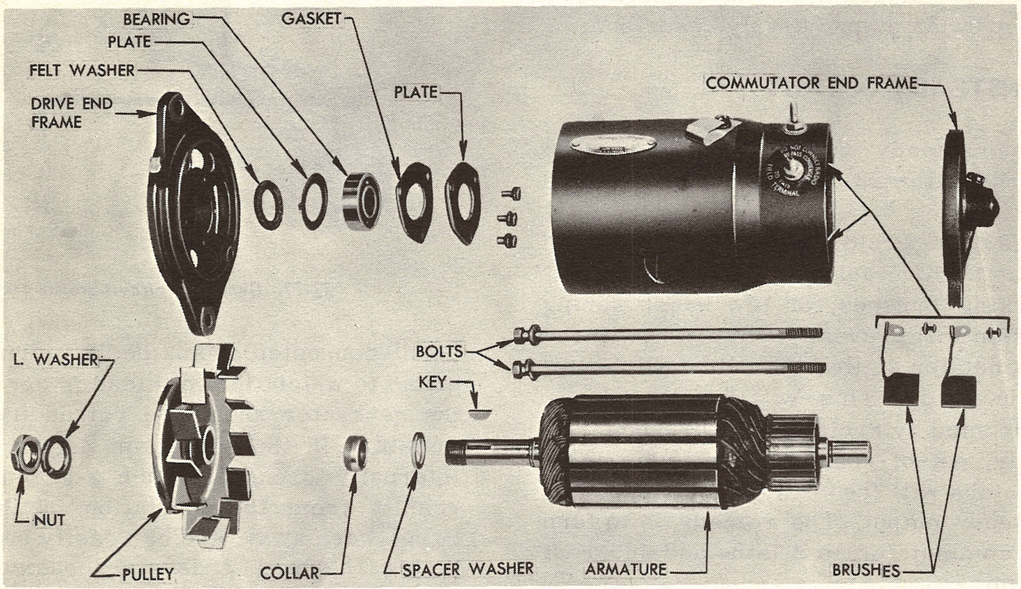
NOISY GENERATORS

The operation of a generator in perfect condition should be virtually noiseless. However, noise will result from improperly seated brushes, a worn commutator, worn bearings, or loose generator mounting or drive pulley.

POLARIZING THE GENERATOR

After a generator has been repaired or tested it should be polarized to make sure it has the correct polarity with respect to the battery in the circuit. If this is not done, the generator may be damaged and in addition the relay contacts may be burned and a run down battery result. The method of polarizing a generator will depend on whether the generator field is grounded through the regulator or is internally grounded.

On an externally grounded generator, Fig. 31-47, after reconnecting the leads, momentarily connect a jumper wire between the "GEN" and "BAT" terminals of the regulator. This permits a momentary surge of current to pass through the generator which will polarize it correctly.



32-18. Disassembled direct current generator. Note the long through bolts which hold the end frames to the main frame.

To polarize a generator with an internally grounded field, Fig. 31-48, disconnect the lead from the field terminal of the regulator and momentarily touch that lead to the regulator ammeter terminal. The resulting surge of current will correctly polarize the generator.

On cars with double contact regulators, disconnect field lead from regulator and ground it. Momentarily place jumper from battery to generator terminals.

IDENTIFYING A AND B GENERATORS

As shown in Fig. 31-47 and Fig. 31-48, there are two basic types of generators used in the automotive field. The A circuit generator (sometimes known as the standard) has the field grounded outside of the generator, while the B circuit (sometimes called the heavy duty) has the field grounded within the generator. As some tests vary slightly with the two types of generators it is necessary to be able to distinguish between them.

A sure method is to disconnect the field wire from the generator field terminal, taking care not to let this wire touch the ground. Connect a voltmeter from the generator field terminal to the ground. Then with the engine operating at a fast idle, a voltage reading indicates that the generator is of the A or standard duty type. If no reading is indicated, the generator has a B circuit and is of the heavy-duty type.

Another method of determining the type of generator is to note the connection between the field and the brushes. This can only be done on generators which have a removable cover band. The procedure is to remove the cover band, and if the generator field coil lead is connected to the insulated brush inside the generator, then the generator is of the A or standard type. If the generator field coil is connected to the grounded brush or the generator field frame, then the generator is of the B or heavy-duty type.

To determine whether a no-charge condition is caused by the generator or the regulator, the best method is to use a voltmeter as previously described. However, another method which does not involve the use of instruments is also frequently used for systems fitted with SINGLE contact regulators of either A or B circuits. On A system circuits, the procedure is to use a jumper wire connecting the field terminal of the generator to the ground. Then with the engine operating at a fast idle, if a charge is shown on the instrument panel indicator, the generator is satisfactory, and the regulator is defective.

In the case of B circuit systems, the procedure is to connect armature terminal of the regulator to the field terminal. If a charge is indicated on the instrument panel indicator with the engine operating at a fast idle, the regulator is defective. If no charge is indicated the generator is defective.

In the methods just outlined, the jumper wire cuts the regulator out of the circuit.

DISASSEMBLING GENERATOR

Place the generator in a bench vise, using the vise as a holding fixture only, taking care not to damage the frame. Remove the two through bolts, Fig. 32-18. Remove the generator commutator end frame by prying between the field frame and commutator end frame with two screw drivers. Remove the end frame and armature assembly from the field frame, Fig. 32-19.

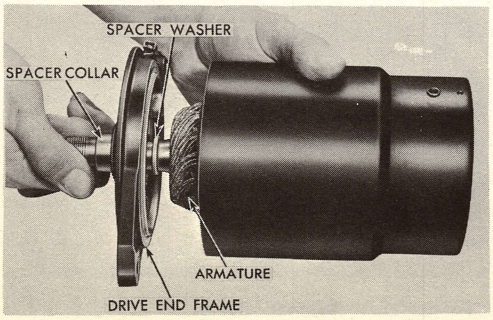
Inspect the brush holders in the frame, making sure they are not loose and are correctly aligned. Check brushes for wear. If worn to less than one half their original length they should be replaced.

Remove the ball bearing from the commutator end of the armature shaft, using a puller designed for that purpose. Remove generator pulley attaching nut from armature shaft, then remove the pulley and fan from the armature shaft. Remove armature from drive end frame assembly. Do not hammer on armature shaft.

Remove bearing retainer plate screws and retainer plate and gasket from end frame, if so equipped.

Remove field and armature terminal nuts, washers and bushings and push terminal studs through frame.

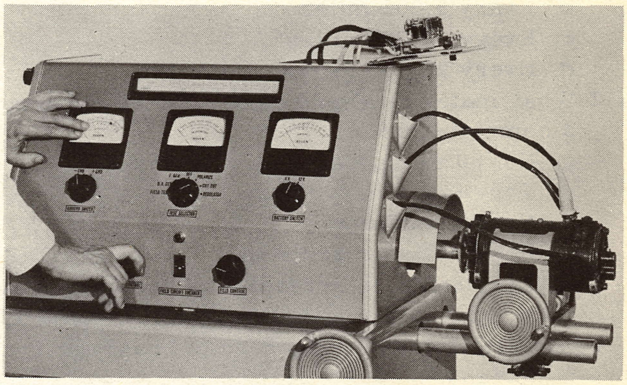
Remove pole screw in each shoe, and remove field coils as an assembly. Removing these screws should be done with the aid of a pole shoe spreader and a screw driver held into the screw slot by means of a lever.


SPACER WASHER
SPACER COLLAR
ARMATURE
DRIVE END FRAME

32-19. Removing armature and end frame from the field frame.

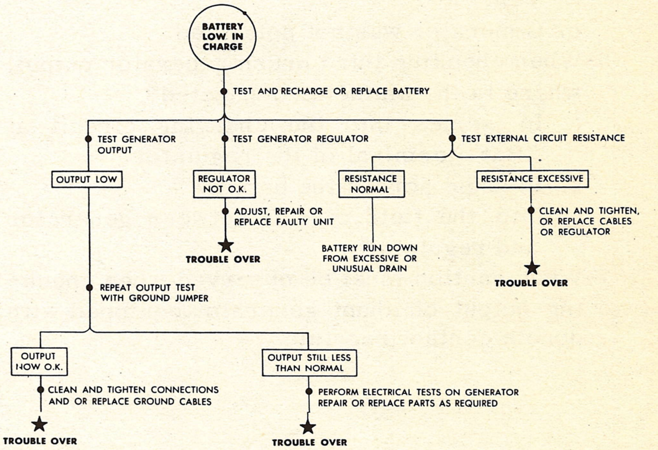
GENERATOR BENCH TEST

After a generator has been overhauled it should be tested to make sure its output comes up to specifications. This is most easily done on a test bench designed for that purpose. Such a bench is shown in Fig. 32-20.



32-20. Generator and regulator being tested on special test bench.

Generator test benches provide means for rotating the generator armature at varying speeds. Field current controls, ammeter, voltmeter and tachometer are also provided. Most generator test benches also provide means for checking the voltage regulator at the same time.


BATTERY LOW IN CHARGE
TEST AND RECHARGE OR REPLACE BATTERY
TEST GENERATOR OUTPUT
TEST GENERATOR REGULATOR
TEST EXTERNAL CIRCUIT RESISTANCE
OUTPUT LOW
REGULATOR NOT O.K.
RESISTANCE NORMAL
RESISTANCE EXCESSIVE
ADJUST, REPAIR OR REPLACE FAULTY UNIT
TROUBLE OVER
BATTERY RUN DOWN FROM EXCESSIVE OR UNUSUAL DRAIN
CLEAN AND TIGHTEN, OR REPLACE CABLES OR REGULATOR
TROUBLE OVER
REPEAT OUTPUT TEST WITH GROUND JUMPER
OUTPUT NOW O.K.
OUTPUT STILL LESS THAN NORMAL
CLEAN AND TIGHTEN CONNECTIONS AND OR REPLACE GROUND CABLES
PERFORM ELECTRICAL TESTS ON GENERATOR REPAIR OR REPLACE PARTS AS REQUIRED
TROUBLE OVER
TROUBLE OVER

32-21. Generating system trouble shooting road map.

GENERATOR SYSTEM TROUBLE SHOOTING

Possible causes of trouble in the generating system are revealed in one of two major symptoms. Either the battery has failed or is low in charge, or the charging rate is too high. First determine the correct symptom by testing or analyzing. Once the symptom has been confirmed, isolate the cause by following the procedure shown in Fig. 32-21, which illustrates the procedure in outline form.

Fig. 32-21 combines the procedures required for determining the particular trouble causing the symptom.

QUIZ - GENERATOR SERVICING, TESTING

1-How often should a generator be inspected?
  a. Every 1,000 miles
  b. Every 5,000 miles
  c. Every 10,000 miles
  d. Every 20,000 miles

2-What material should be used when cleaning a commutator?
  a. No. 80 sandpaper
  b. Very fine emery paper
  c. No. 00 sandpaper
  d. Powdered carbarundum

3-After turning a generator armature in a lathe what additional operation is required?

4-Why is the tension of generator brush springs important?

5-If the inner surface of a generator cover band is found to be covered with globules of solder, what is indicated?
  a. Generator has been operating at excessive speed
  b. Generator was producing excessive current
  c. Generator was not polarized

6-When checking third brush generator output, where is the ammeter connected?
  a. In series into the charging circuit at "Bat" terminal of the regulator
  b. In shunt across the battery
  c. Into the field circuit between generator and regulator

7-What caution must be observed when checking output of shunt generator equipped with double contact regulator?
  a. Never ground generator field with regulator connected to generator
  b. Always be sure that field is grounded
  c. Use a jumper betweeen field and armature

8-When checking the output of B-circuit generators, where should the jumper be connected?
  a. From armature to field terminal
  b. From armature to ground
  c. From field to ground

9-To test the field circuit of an A-circuit generator for an open circuit, where should the test prods of the test lamp be placed?
  a. One on field terminal, other on ground
  b. One on field terminal, other on armature
  c. One on armature terminal, other on ground

10-List three causes for low or unsteady output of a generator.

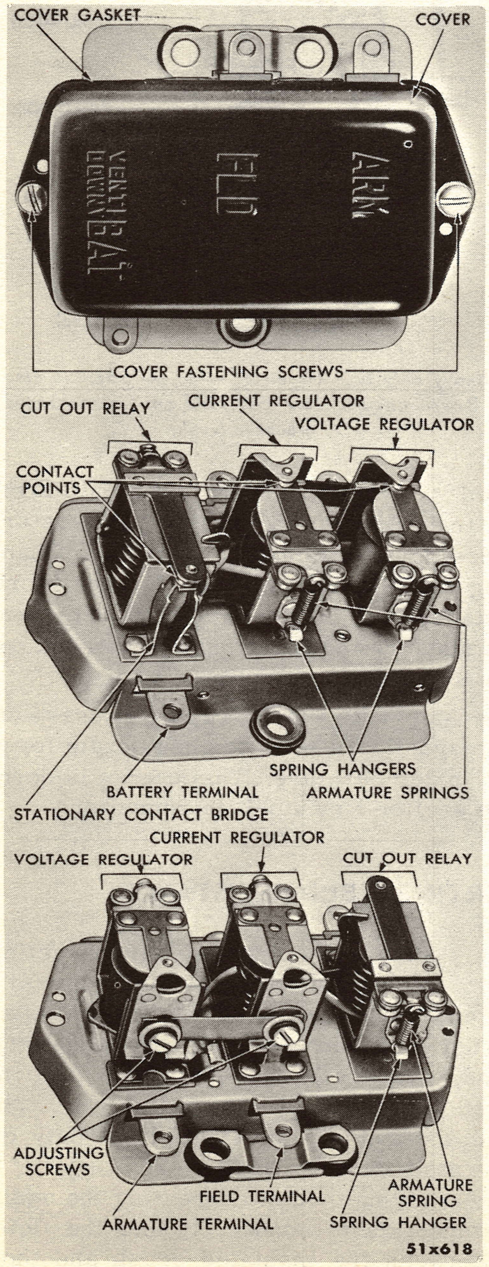
11-If tests show that generator output is excessive, even after F terminal has been disconnected, where will the trouble be?
  a. In the regulator
  b. In the generator
  c. Poor ground connection
  d. Discharged battery

12-How would you polarize an A-type generator?

13-How would you polarize a B-type generator?

14-Where is the field circuit of a B-type generator grounded?
  a. Within the generator
  b. Outside the generator

GENERATOR
REGULATORS AND RELAYS


COVER GASKET
COVER
ARM
FLD
COVER FASTENING SCREWS
CUT OUT RELAY
CURRENT REGULATOR
VOLTAGE REGULATOR
CONTACT POINTS
SPRING HANGERS
BATTERY TERMINAL
ARMATURE SPRINGS
STATIONARY CONTACT BRIDGE
CURRENT REGULATOR
VOLTAGE REGULATOR
CUT OUT RELAY
ADJUSTING SCREWS
FIELD TERMINAL
ARMATURE SPRING
ARMATURE TERMINAL
SPRING HANGER
51x618

33-1. ***Auto-Lite three unit regulator, showing cover, together with front and rear views of regulator.***

In order to control the output of an automotive generator, the system is provided with a regulator. The regulator is basically an automatic switch which controls the generator output so damaging high voltage and high current will not damage the battery, generator or other units of the system.

The regulator, Fig. 33-1, controls the voltage and the current by automatically cutting in or out additional resistance in the field circuit of the generator. Varying the resistance of the field circuit, will alter the amount of current passing through the generator fields. This in turn changes the strength of the magnetic field, and in that way the generator output is regulated.

Such regulation is needed on a shunt-wound generator as the output of a shunt-wound generator would continue to increase as the rotation of the armature increased. With the regulator, the output is maintained at a constant rate, see Fig. 31-44.

The regulator as used on most automotive passenger cars consists of three elements or units; a cutout relay, a voltage regulator, and a current regulator, Fig. 33-1. However, in some installations using a third brush type generator (now used mostly on farm tractors) only a cutout relay is used. On other installations, a cutout relay and voltage regulator are used. Virtually all current passenger cars use a regulator consisting of a cutout relay, a current regulator, and a voltage regulator.

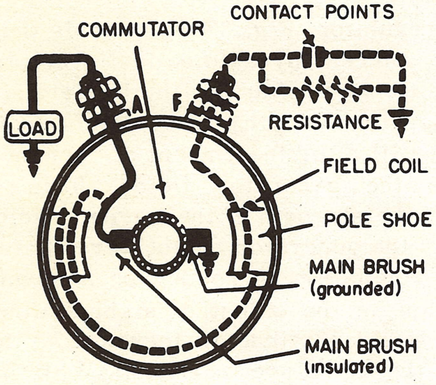
CUTOUT RELAY

The purpose of the cutout relay is to prevent the battery from discharging through the generator, when the engine is stopped, or is turning at such a slow speed that the generator is not producing enough voltage to charge the battery.

VOLTAGE REGULATOR

The purpose of the voltage regulator is to prevent the circuit voltage from exceeding a predetermined safe value, and also to maintain a constant voltage in the system. As a result, when the battery needs charging, it automatically cuts resistance out of the field circuit, thereby increasing the flow of current in that circuit, with the further result that output is increased. When the battery becomes fully charged, the resistance is cut into the field circuit, so that the charging rate is decreased.

The battery will actually regulate its own charge, within certain temperature limits, if the voltage in the circuit is kept at a constant value. This is due to the fact that the opposing or counter voltage of the battery increases as the battery comes up to charge. A constant-system voltage becomes less and less able to overcome this increasing counter voltage so that the charge rate to the battery automatically tapers off.



33-2. Standard duty type circuit of shunt generator. This is also known as the A-type circuit. Note that the field coil is connected to the insulated brush.

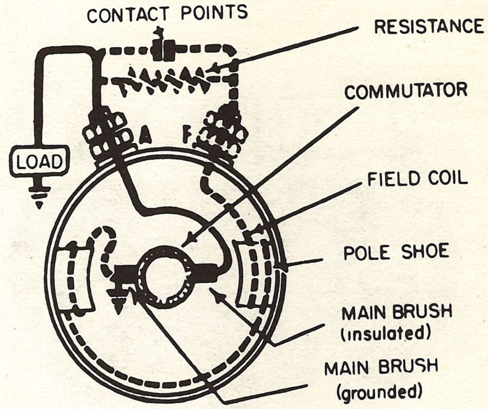
CURRENT REGULATOR

The current regulator is a magnetic switch which operates in the charging circuit to protect the generator from overload by limiting its output to a safe value. The current regulator has only a single winding of heavy wire as it carries the entire output of the generator.

TEMPERATURE COMPENSATION

All windings used in cutout relays, voltage regulators and current regulators are wound with copper wire. The resistance of these windings increases as they become warm. It is therefore necessary to compensate for this change in resistance, otherwise the degree of "magnetic pull" exerted by these windings would vary which in turn would cause the voltage and current settings to change.

In most designs, the necessary temperature correction is provided by means of a bi-metallic hinge on the armature of the relay or regulator. This bi-metallic hinge appears to be made of a thin strip of spring steel. Actually it is made of two thin layers of different metals which are fused together. These metals have different rates of expansion as the result of heat. Thermostatic action then takes place as the hinge gets hot; one side expands more than the other causing the hinge to bend. This type of hinge applied to the regulator or relay armature tries to bend with increasing temperature and reduces the tension of the spring. Change of spring tension compensates for the increased resistance of the copper windings as the temperature goes up and the regulator will now operate at the same or slightly lower voltage.



33-3. Heavy duty type circuit of shunt generator is also known as the B-type circuit. Note that field coil is connected to the grounded brush.

The Auto-Lite voltage regulator uses a nickel-iron magnetic by-pass to compensate for variations in temperature. This design is described in the section on Auto-Lite regulators.

INSERTING FIELD RESISTANCE

There are two methods of connecting the additional resistance in the field circuit, Fig. 33-2 and 33-3. In Fig. 33-2, the resistance is inserted between the field windings and the ground, and the field is connected to the insulated brush inside the generator. This is known as the A circuit or light duty circuit and is also shown in Fig. 31-47.

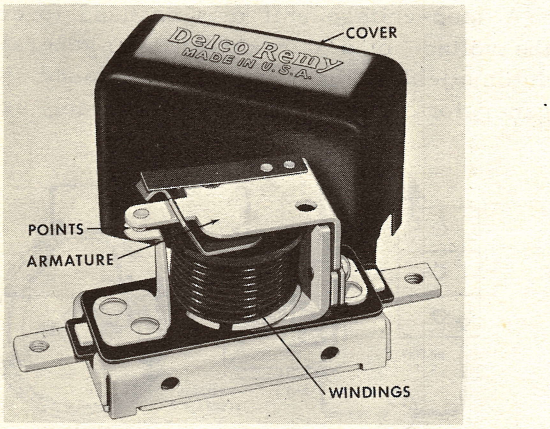
The other method of connecting the additional resistance, is to connect it into the field circuit between the insulated brush and the field windings, Fig. 33-3. This is known as the B circuit, or heavy-duty circuit.

The A circuit is used primarily by General Motors and Chrysler passenger cars, while the B circuit is used on Ford-built passenger cars. However, some manufacturers are now using both A and B circuit generating systems.

GENERATOR CUT-OUT RELAY

In order to prevent the starting battery from discharging through the generator when the engine is stopped, a cut-out relay, Fig. 33-4, is placed in the circuit. This relay closes the circuit between the generator and the battery, when the generator speed is high enough to develop sufficient voltage to charge the battery. It also opens the circuit when the generator speed is too low to develop charging voltage.

Third brush generators as used on some farm tractors are provided with only a cut-out relay, Fig. 33-4. In such cases the relay is mounted on top of the generator.



33-4. Typical cut-out relay.

As shown in Fig. 33-5, the cut-out relay is provided with two windings assembled on a single core. One winding consists of a few turns of heavy wire which is in series with the charging circuit, while the other winding is a shunt winding of many turns of fine wire which is shunted across the generator.

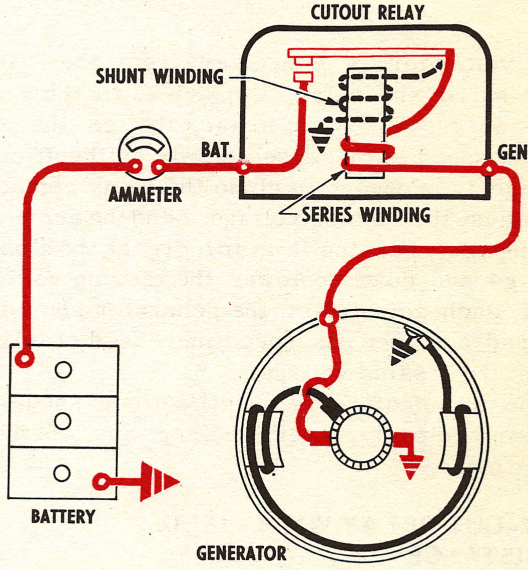
The windings and core of the cut-out relay are assembled in a frame and a flat steel armature with a contact point is attached to the frame by a flexible hinge. When the generator is not turning fast enough to develop sufficient charging voltage, the armature contact point is held away from the stationary point by the tension of a flat spring.

When the generator builds up sufficient voltage to charge the battery, the current flowing through the windings of the cut-out relay will produce sufficient magnetism to pull the armature toward the relay core. This will close the relay contact points, completing the circuit between the battery and the generator.

The current passes through the series winding in the proper direction to add to the magnetism which holds the armature down. When the generator speed drops, current will flow from the battery to the generator. This reverse flow of current through the series winding causes a change in the magnetic field. However, the magnetic field of the shunt winding remains the same with the result that the magnetic field is weakened and the flat spring pulls the armature away from the core and the contact points are opened. This opens the circuit between the generator and the battery.

CUT-OUT RELAY ADJUSTMENT

The cut-out relay requires three checks and adjustments. These are air gap, point opening and voltage required to close the contacts. When adjusting the air gap and the point opening it is necessary to disconnect the battery.

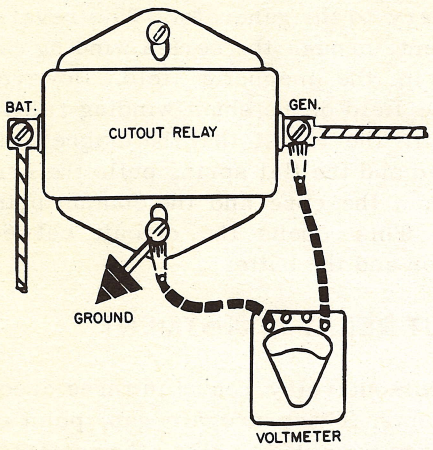


33-5. Windings and connections of cut-out relay with third brush generator. Cut-out relay series winding and charging circuit is shown in red. Cut-out shunt winding in dotted black and generator field circuit inside generator shown in solid black.

The air gap is the space between the armature and the core and is measured when the armature is held down so that the contact points are closed. To adjust, loosen the adjusting screws and raise or lower the armature until the desired gap is obtained. Be sure the points are in alignment and the adjusting screws are tightened when the adjustment is completed.

The point opening or gap is adjusted by bending the upper armature stop.

A voltmeter is needed to check the voltage at which the points of the cut-out relay close.



33-6. Connections for checking voltage at which cut-out relay points close.

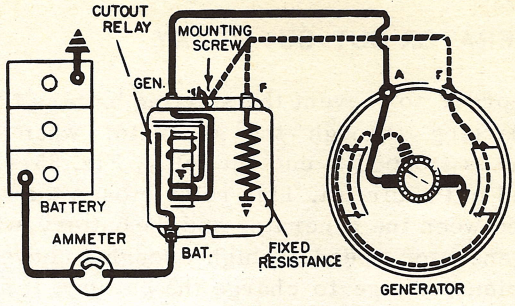
The voltmeter is connected from the "Gen" terminal of the relay, Fig. 33-6, to the relay base or ground. When making the test the generator speed is increased slowly until sufficient voltage is produced to close the relay contacts. To adjust the closing voltage, bend the armature spring post, bending it up to increase the closing voltage and down to lower the closing voltage. After each adjustment, the generator should be stopped and then its speed increased slowly to check the closing voltage.

The manufacturer's specifications should be followed closely when making any of these adjustments.

CUT-OUT RELAY WITH FIELD RESISTANCE

As previously pointed out, generator output can be controlled by inserting a resistance in the field circuit. The resistance, either fixed or variable, is usually mounted on the same base as the cut-out relay. The relay is of the conventional type and the connections are shown in Fig. 33-7. On some installations, this additional resistance was cut out of the circuit whenever the headlights were turned on. Units with variable resistance are also available, Fig. 33-8.

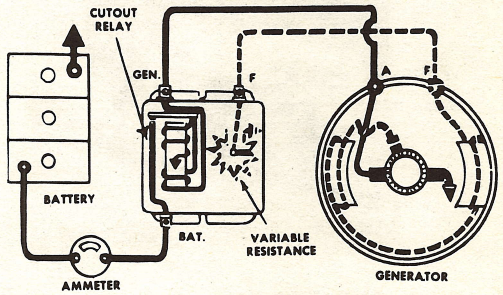
In Fig. 33-7 it will be noted that full generator output could be obtained by connecting the generator field lead under the relay mounting screw (instead of the resistance terminal) and the generator will operate as a conventional third brush unit.



33-7. Cut-out relay with fixed resistance.

STEP-VOLTAGE GENERATOR CONTROLS

A step-voltage unit may be used to control the voltage of a third-brush type generator by automatically inserting a resistance in the generator field circuit. These are only used on generators which have the field circuits insulated in the generator but are grounded in the voltage control unit.



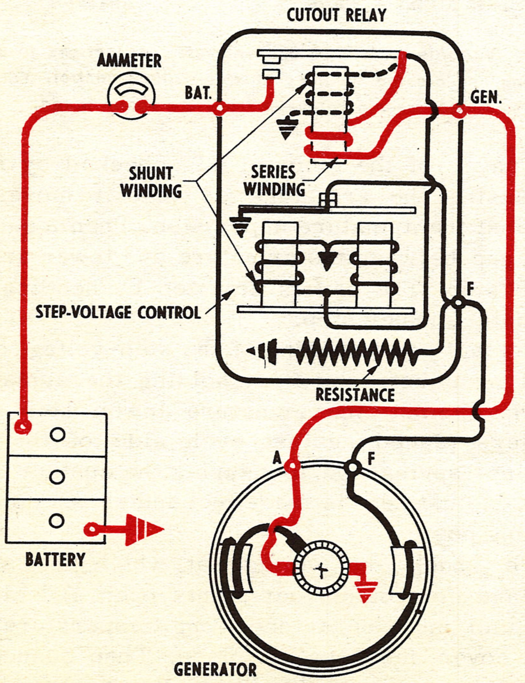
33-8. Wiring diagram of cut-out relay with variable resistance.

The cut-out relay used in conjunction with the step-voltage control has two windings which are assembled on a single core; a series winding consisting of a few turns of heavy wire and a shunt winding consisting of many turns of fine wire. The shunt winding is shunted across the generator, while the series winding is in series with the charging circuit. The armature with its contact point is made of flat steel and is attached to the frame by means of a flexible hinge. When the generator is not operating the contact points are held open by means of a spring.

The cut-out relay on a step-voltage control unit operates in the same manner as a conventional cut-out relay which was previously explained.

The step-voltage control unit is provided with two shunt windings as shown in Fig. 33-9 which are placed on two cores. Above the cores is a flat steel armature with a contact point so arranged that the points are open when the armature is not attracted to the core. When the points are closed, the generator field circuit will be grounded.

When the battery voltage is low and there is a heavy load on the generator, the generator voltage will also be relatively low. Under such conditions the step-voltage control unit will not operate and as a result the generator output will increase to its maximum. However, if the load on the generator is reduced and the battery is nearly fully charged, the circuit voltage would normally increase. This increasing voltage causes a corresponding increase of voltage on the shunt windings and also an increase in the strength of their magnetic field. When the voltage reaches the value for which the unit is adjusted, the magnetic field will pull down the armature, opening the contact points. With the points open, all the current from the field will then pass through the resistance so that the generator output will be reduced. This resistance will be kept in the circuit as long as the battery retains a satisfactory charge. When the charge has decreased, the contact points will again close, shorting out the field resistance.



33-9. Wiring diagram of Delco-Remy step-voltage control. Cutout series winding is shown in red and shunt winding in dashed black. Step-voltage control shunt winding shown in solid black.

MAINTENANCE OF STEP-VOLTAGE CONTROL UNITS

When checking and adjusting a step-voltage control unit, the battery must be disconnected and the work is more easily done if the unit is removed from the vehicle. To prevent damage to the relay contact points and other electrical equipment, it is important that the cut-out relay points should never be closed by hand when the battery is connected to the step-voltage control unit.

When checking a step-voltage control unit it must be at operating temperature and the cover must be in place. Also after any tests or adjustments or when a new unit is installed, the generator on the vehicle must be polarized after the connections are made but before the engine is started.

To polarize a generator equipped with a step-voltage control unit, place a jumper lead momentarily between the "Gen" and "Bat" terminals of the unit.

STEP-VOLTAGE TROUBLE SHOOTING

When the starting battery is fully charged and the charging rate is low, the system is operating correctly as the control unit automatically reduces the charging rate when the battery is fully charged.

However if the battery is fully charged and the charging rate remains high, it indicates that the step-voltage control unit is not operating correctly.

To determine whether the difficulty is in the generator or step-voltage control unit, disconnect the "F" lead from the control unit with the generator operating at medium speed. If the charging rate remains high, the generator field is either grounded in the generator or in the wiring harness. If the generator output decreases when the "F" terminal lead is disconnected, reconnect the lead and with the generator operating at medium speed, check the contact points of the step-voltage control unit to see if they open at the correct value. If the contact points are opening correctly, the generator field circuit is grounded inside the step-voltage control unit, with the result that the resistance is not being inserted in the circuit. If the points do not open, the voltage setting may be too high and should be adjusted.

If both generator and step-voltage control unit, together with the wiring are in good condition, and the charging rate is excessive (with a fully charged battery), it will be necessary to readjust the position of the third brush. Moving the brush in the direction opposite to that of the rotating armature, will reduce the charging rate.

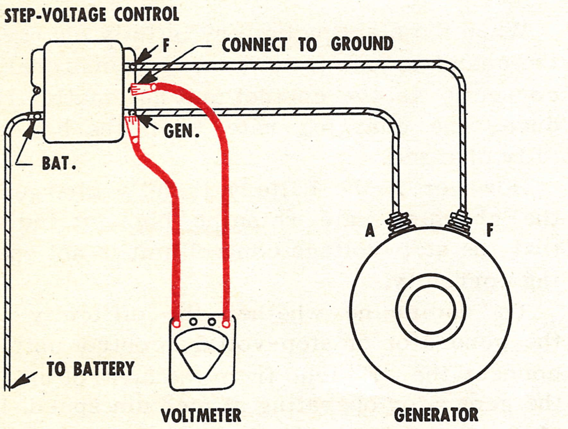
Under ideal conditions, the generator output should be approximately the same as the load requirements, plus to or three amperes to maintain a satisfactory charge on the battery.

The cut-out relay on a Delco-Remy step-voltage control unit requires three checks and adjustments: air gap, point opening and the closing voltage. The battery must be disconnected when making these adjustments.

To adjust the air gap, hold the armature down so that the contacts are closed, then with a thickness gauge measure the gap between the armature and the core. Two screws at the back of the cut-out relay are provided for adjustment.

The point opening is adjusted by bending the upper armature stop.

The electrical connections to determine the closing voltage of the cut-out relay are shown in Fig. 33-10. Note that one lead from the voltmeter is connected to the "Gen" terminal and the other to the base of the unit. With the voltmeter connected as indicated, slowly increase the speed of the generator and note the voltage at which the relay contacts close. The closing voltage is adjusted by bending the armature spring post. Bending the post upward will increase the tension of the spring and also the voltage at which the points close. Bending the post down will decrease the closing voltage.

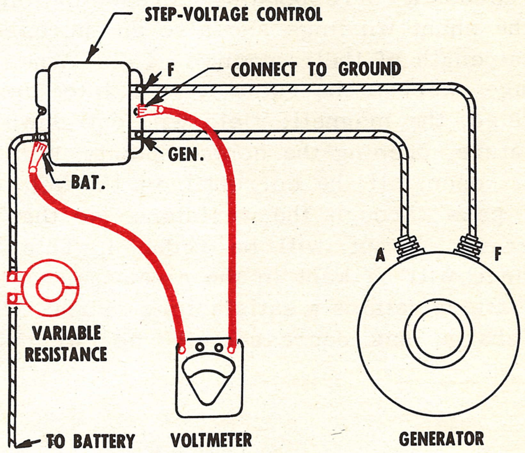


33-10. Voltmeter connections for checking the closing voltage of cutout relay are shown in red.

The Delco-Remy step-voltage control unit requires five checks and adjustments: flat spring tension, air gap, armature travel, point opening and voltage setting.

The pressure between the step-voltage contact points is determined by the tension of the flat spring. This spring tension should be 3/4 oz. at the instant the points separate. To measure the tension, push the armature down, until the points almost open, then use a spring gauge to measure the downward pull required to open the points. Adjustment is made by bending the flat spring.

To check the air gap, hold the armature down against the armature lower stop by placing fingers on either side of the flat contact spring. Adjust the air gap by bending the armature lower stop.



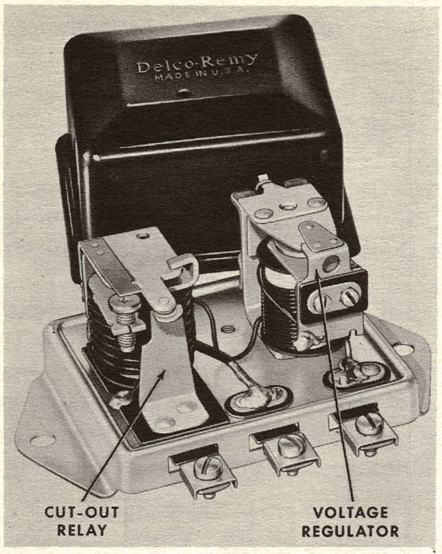
33-11. Variable resistance and voltmeter connections to check opening and closing voltages of step-voltage control. Variable resistance and voltmeter leads are shown in red.

Travel of the armature is checked by first releasing the armature so that it moves up against the armature upper stop. Then measure the gap between the armature and lower armature stop. The gap is adjusted by bending the armature upper stop.

Contact point opening of the step-voltage control is adjusted by first holding the armature down against the armature lower stop with fingers placed against each side of the flat contact spring and measuring the contact point gap. Adjustment is made by bending the contact spring post.

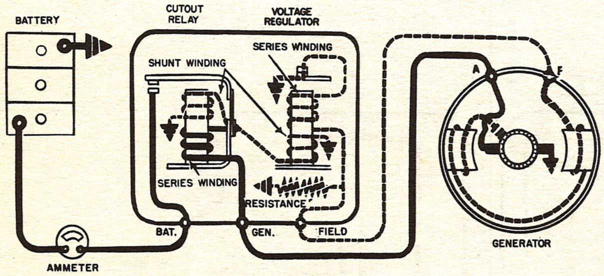
To check the voltage at which the step-voltage control contact points open and close, the unit must be at operating temperature and the cover must be in place. Then connect a voltmeter across the "Bat" terminal and the base of the unit. Also connect a variable resistance in series between the "Bat" terminal and the starting battery as shown in Fig. 33-11.

Increase the generator speed gradually and note the voltage at which the contact points open. Then decrease the generator speed and note the voltage at which the contacts close. If the battery needs charging, the voltage will not increase sufficiently to cause the contacts to open. Under such a condition it will be necessary to cut in resistance slowly by means of the variable resistance, with the generator operating at medium speed to provide sufficient voltage to open the contact points.



33-12. Two unit Delco-Remy regulator with cover removed.

The opening voltage is adjusted by bending the lower spring hanger, while the closing voltage is adjusted by changing the air gap. After adjusting the closing voltage it may be necessary to readjust the contact point opening in order to keep it within the required limits.



33-13. Wiring diagram of two unit Delco-Remy regulator.

DELCO-REMY TWO UNIT REGULATOR

The Delco-Remy two unit regulator, Fig. 33-12, is for use with third brush generators. Diagram of connections for the light duty type or A circuit is shown in Fig. 33-13. It consists of a cut-out relay and a voltage regulator unit. The operation of the cut-out relay is similar to that previously described. The voltage regulator, however, differs from the step-voltage control unit previously described. The step-voltage unit does not vibrate, but simply cuts a resistance in and out of the field circuit. The voltage regulator is a voltage limiting device designed to prevent the voltage from exceeding a specified maximum. In operation the contact points vibrate.

The voltage regulator has two windings assembled on a single core, a high resistance shunt winding consisting of many turns of fine wire, and a low resistance series winding consisting of a few turns of heavy wire. As shown in the diagram, Fig. 33-13, the shunt winding is shunted across the generator, while the series winding is in series between the generator field circuit and the regulator contact points.

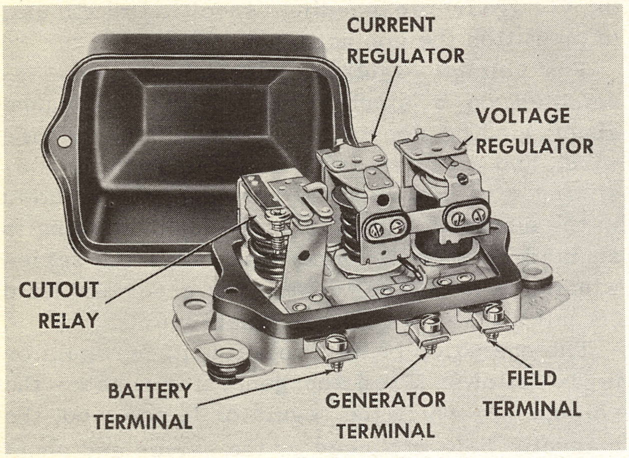
The operation of the two unit voltage regulator is as follows: When the generator reaches the voltage for which the regulator is adjusted, the magnetic field produced by the series and shunt windings, overcomes the tension of the armature spring and pulls the armature down, separating the contact points. This inserts a resistance into the generator field circuit so that the generator field voltage and current are reduced. Reduction of the generator voltage reduces the magnetic field of the regulator shunt winding. The opening of the contact points opens the series winding of the regulator circuit so that the magnetic field collapses completely. As a result, the contact points close. With the points closed, the generator field circuit is grounded, so that generator current and voltage increase, and the cycle is repeated. This opening and closing of the contact points occurs at approximately 200 per minute and by maintaining a constant voltage, the generator supplies varying amounts of current in accordance with the requirements of the battery and electrical load.

DELCO-REMY THREE UNIT REGULATOR

The Delco-Remy three unit regulator, Fig. 33-14, as used mostly on passenger cars is of the "A" circuit type and grounds the field circuit in the regulator. This type regulator starts with serial number 1118825 and has only a single winding on the voltage regulator unit as compared to the two windings used on the two unit regulator and some three unit regulators. Because of this difference in winding on the voltage unit there is a difference in the method of checking and adjusting the voltage setting.

This regulator, Fig. 33-14, is of the single contact point type and the wiring diagram is shown in Fig. 33-15.

CUTOUT RELAY: When the generator voltage builds up to a value great enough to charge the battery, the relay armature is pulled down, closing the contacts. The current from the generator now passes through the series winding adding to the magnetism holding the armature down and the points closed. When the generator stops or slows down, current begins to flow from the battery to the generator through the series winding which reverses the magnetic field of the relay, releasing the armature and opening the points. This breaks the circuit between the battery and the generator.

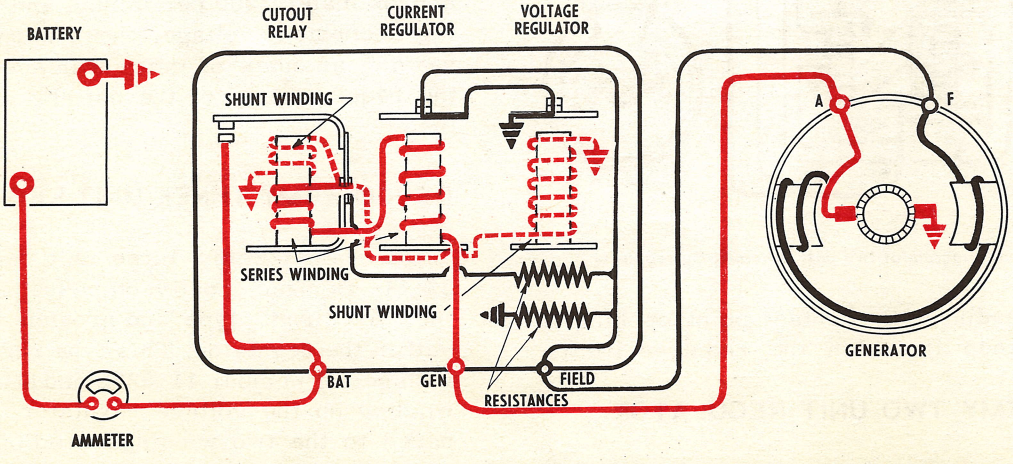


33-14. Typical three unit single contact Delco-Remy regulator as used on A circuit systems.

VOLTAGE REGULATOR: The voltage regulator has a single shunt winding of many turns of fine wire, which is connected across the terminals of the generator. (Some models of regulators have a shunt winding and also a series winding as described for the two-unit regulator). When the voltage regulator unit is not working, the contact points are closed, and the generator field circuit is completed to the ground through them.

When the generator voltage reaches the value for which it is adjusted, the magnetic field produced by the winding, overcomes the tension of the spring (holding the contacts closed), pulls the armature down and opens the contact points. This inserts resistance, Fig. 33-15, into the generator field circuit. This reduces the generator field current and voltage, which in turn reduces the magnetic field of the regulator shunt winding. As a result, the armature is pulled away from the core and the contact points again close. With the points closed, the generator field circuit is grounded causing the generator current and voltage to increase. The above cycle continues at many times per second, regulating the voltage to a predetermined value.

CURRENT REGULATOR: The current regulator, mounted in the center of the unit, Fig. 33-14, has a series winding of a few turns of heavy wire, and the entire output of the generator passes through this winding, Fig. 33-15. When the current regulator is not working, the tension of the spiral spring holds the armature away from the core so the points are in contact In this position, the generator field circuit is completed to ground through the regulator con-



33-15. Wiring diagram of Delco-Remy standard three-unit regulator. The series windings in the cutout relay and current regulator are shown in solid red and the shunt windings in the cutout relay and voltage regulator are shown in dashed red, while the field circuit and resistors are in black.

tact points in series with the voltage regulator contact points.

When the generator current output reaches the value for which the unit is set, the magnetic pull draws the armature down, opening the contact points. This inserts a resistance into the generator field circuit, reducing the field current and output. This in turn reduces the pull on the armature of the current regulator, allowing the spiral spring to pull the armature up and close the contact points. This grounds the generator field circuit, causing the generator output to again increase. This cycle is repeated many times a second, limiting the generator output so it does not exceed its rated maximum.

RESISTANCES: The current and voltage regulator units use two common resistances, Fig. 33-15. One is inserted in the field circuit when either the current or voltage regulator unit operates. The second resistance is connected between the regulator field terminal and the cutout relay frame, which places it in parallel with the generator field coils. The sudden reduction in field current occuring when either the current or voltage regulator contact points open, is accompanied by a surge of induced voltage in the field coils as the magnetic field changes in strength. These surges are partly dissipated by the two resistors and reduce the arcing at the contact points.

REGULATOR POLARITY: Some regulators are designed for use with systems having the negatime terminal of the battery grounded, while others are designed for use with positive grounded systems. Using the wrong polarity regulator on a system will cause the regulator contacts to pit badly and shorten its life. Regulators are clearly marked on their base to indicate the system for which they are designed.

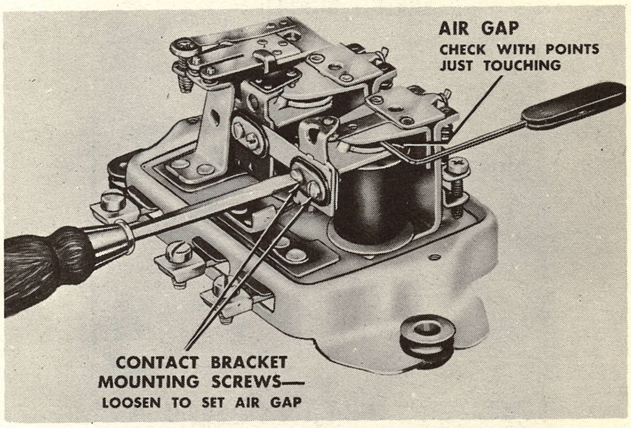
REGULATOR CHECKS AND ADJUSTMENTS

When checking and adjusting the three unit Delco-Remy regulator, the procedure should be in the following order:

a. Bring voltage regulator to operating temperature.
b. Check voltage regulator.
c. Check cutout relay.
d. Bring current regulator to operating temperature.
e. Check current regulator.

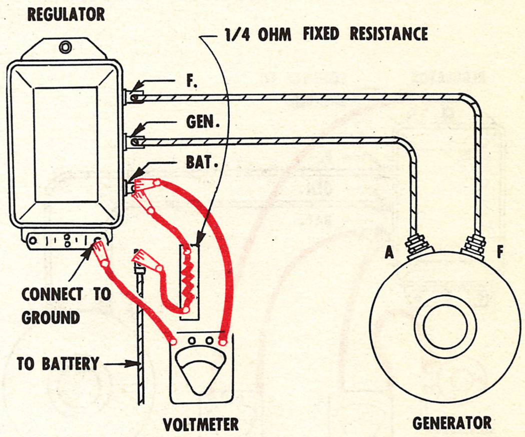
VOLTAGE REGULATOR ADJUSTMENT: To adjust air gap, push down on armature until contact points are just touching. Measure the air gap between the armature and winding core, Fig. 33-16. Adjust by loosening contact mounting screws and moving mounting bracket as required. In most cases this air gap is .075 in., but manufacturer's specifications must be consulted.

VOLTAGE SETTING: There are several methods of making this setting. The following is known as the "Fixed 1/4 ohm resistance method" and can be used for either 6 or 12-volt systems, using single contact regulators.


AIR GAP
CHECK WITH POINTS JUST TOUCHING
CONTACT BRACKET MOUNTING SCREWS—
LOOSEN TO SET AIR GAP

33-16. Adjusting air gap on Delco-Remy voltage regulator.

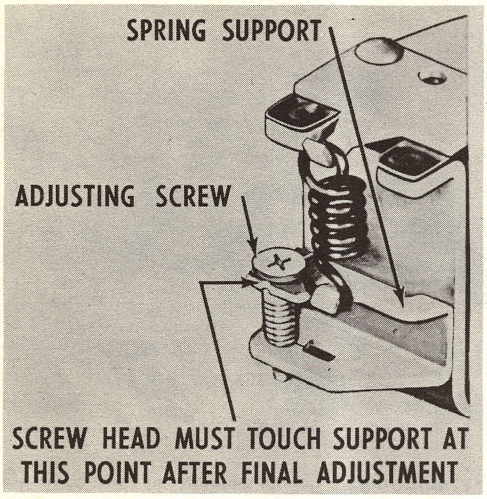
Make connections as shown in Fig. 33-17. Bring regulator up to operating temperature by operating generator at 3500 r.p.m. (generator) for 15 minutes. Regulator cover must be in place. It is not necessary to measure the current while test is being made, but it is important that no load, other than ignition, be on the gen-



33-17. Fixed resistance and voltmeter connections to check voltage regulator settings of A circuit systems. Fixed resistance and voltmeter leads shown in red.

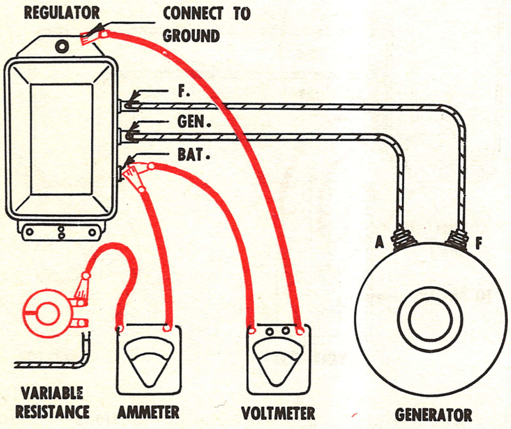
erator. Cycle the generator by reducing its speed until the contacts of the cutout relay open. Then bring generator back to 3500 r.p.m. (Engine about 1500 r.p.m.) Note reading on voltmeter.

Adjust voltage setting by turning adjusting screw, Fig. 33-18. To increase voltage, turn screw clockwise. After each setting recycle generator.


SPRING SUPPORT
ADJUSTING SCREW
SCREW HEAD MUST TOUCH SUPPORT AT THIS POINT AFTER FINAL ADJUSTMENT

33-18. Voltage and current regulator settings are adjusted by means of adjusting screw.

VARIABLE RESISTANCE METHOD: Make connections as shown in Fig. 33-19. Start generator and adjust variable resistor to 1 - 10 amps. Operate generator at specified speed for 15 minutes. Cycle the generator as previously explained and adjust voltage setting as shown in Fig. 33-18. Test specifications are given for a normal room temperature of 80 deg. If regulator is adjusted at room temperature higher than 80 deg., set voltage 0.1 volt less than specified normal setting for each 10 deg. above 80 deg. For lower room temperatures, set voltage setting 0.1 volt more for each 10 deg. below 80 deg.

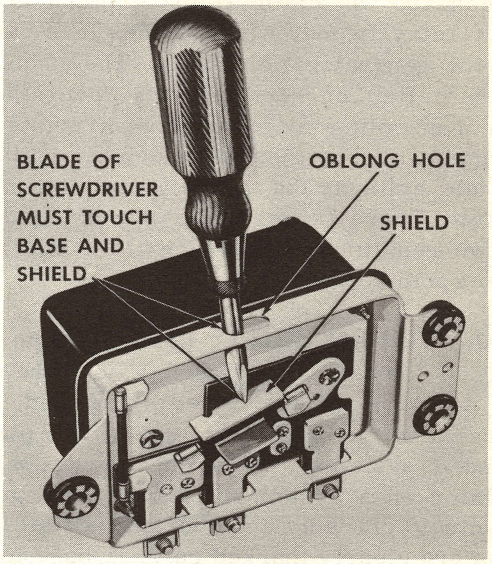

REGULATOR
CONNECT TO GROUND
F.
GEN.
BAT.
A
F
VARIABLE RESISTANCE
AMMETER
VOLTMETER
GENERATOR

33-19. Variable resistance method meter connections for checking voltage regulator setting on A circuit systems.

CUTOUT RELAY ADJUSTMENT: The method of making this adjustment was given in detail under the heading "Cut out Relay." In Fig. 33-6, only a cutout relay is shown, however, the procedure is the same when the cutout forms part of a regulator, with one lead from the voltmeter being connected to the ground and the other to the generator terminal of the regulator.

CURRENT REGULATOR ADJUSTMENT: It is necessary to check the air gap and the current setting of current regulators.

The air gap check and adjustment is made in the same manner as was described for the voltage regulator.


BLADE OF SCREWDRIVER MUST TOUCH BASE AND SHIELD
OBLONG HOLE
SHIELD

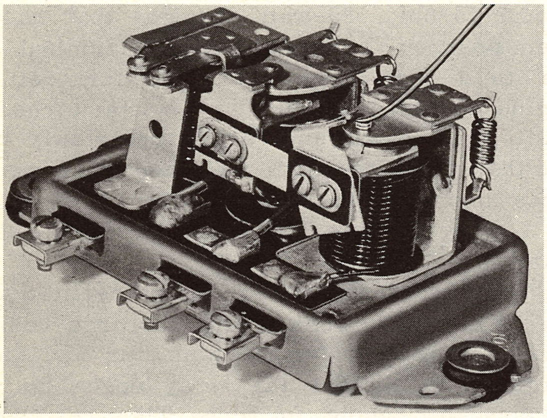
33-20. Quick method of shorting voltage regulator in order to check current regulator setting.

To check the current regulator setting, the voltage regulator setting must be prevented from operating. One method is shown in Fig. 33-20. The procedure is to insert a screwdriver through the hole in the regulator base, with the screw driver firmly contacting the regulator base and the shield at the same time. When making the current setting, connect an ammeter in series with the regulator and the wire leading to the battery. Turn on all lights and accessories and operate the generator at specified speed for 15 minutes with the cover in place. Short the voltage regulator by inserting the screw driver through the base. Cycle generator and note current setting. Adjustment is made by turning screw controlling spring tension of current regulator.

Another method of adjusting the setting of the current regulator is known as the jumper lead method. This method is used only on current regulators without temperature compensation. An ammeter is connected into the charging circuit as in the previous method and a jumper lead is placed across the voltage regulator points. With all the lights and accessories turned on, operate generator at specified speed and note current setting. Adjust spring tension of current regulator to limit current to desired value. Make final adjustment by increasing tension.

CHECK FOR OXIDIZED REGULATOR POINTS

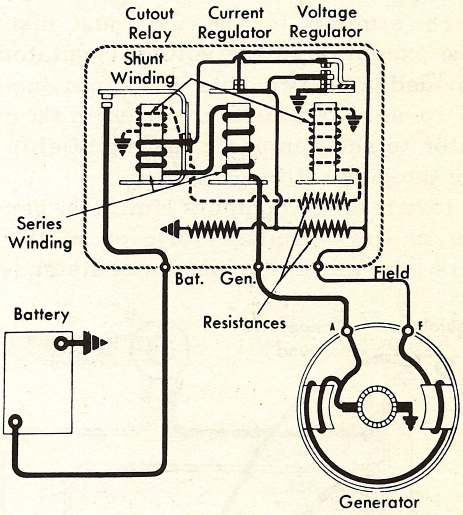
Oxidized regulator points may be the cause of low generator output or discharged starting battery. The following check should therefore be made to determine if the regulator points are oxidized. Connect an ammeter in the charging circuit and turn on the headlights. Operate the generator at a speed which will produce a charge rate of 5 amps. Using a short jumper lead, connect the field terminal of the regulator to the ground. If the generator output increases more than 2 amps., oxidized regulator contact points are indicated, and they should be cleaned.



33-21. Only a spoon or riffler file should be used for cleaning the flat points of Delco regulators. Cutout relay points should be cleaned with fine crocus cloth.

CLEANING DELCO-REMY REGULATOR POINTS

Regulator contact points will not operate indefinitely without some attention and the great majority of regulator trouble can be overcome by simple cleaning of the current and voltage regulator points, plus occasional adjustment. The large flat points should be cleaned with a spoon or riffler file, Fig. 33-21. On negative grounded regulators which have the flat contact point on the regulator armature, loosen the upper contact bracket mounting screws so that the bracket can be tilted to one side, Fig. 33-21. On positive grounded regulators, the flat point is in the upper contact bracket so the bracket must be removed for cleaning the points. A flat file cannot be used successfully to clean the flat contact points since it will not touch the center where wear is most apt to occur. Emery cloth or sandpaper must never be used to clean contact points.



33-22. Wiring diagram of type A circuit with double contact regulator.

Remove all oxides from contact points. It is not necessary to remove any pitting or cavities that may have developed.

Cutout relay contact points are of soft material and should not be cleaned with a riffler file. These should be cleaned with crocus cloth or fine abrasive material. Points should then be cleaned with fresh commercial solvent to remove any foreign material.

DELCO-REMY DOUBLE CONTACT REGULATOR

Because of increased electrical load, many cars, particularly those equipped with air conditioning are provided with regulators of the double contact type, Fig. 33-22.

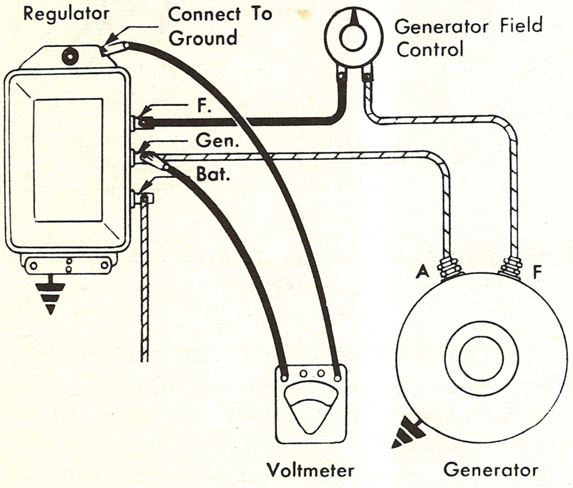
On all cars with double contact regulators, NEVER GROUND the generator field with the regulator connected to the generator. This will instantly burn the upper set of contact points of the regulator.

Before polarizing the generator of a system fitted with a double contact regulator, always insulate the brushes from the commutator.

The instruction given previously for checking current output, voltage output, testing for ground in generator, generator circuit resistance test, and generator ground circuit test are also applicable to double contact regulator systems.

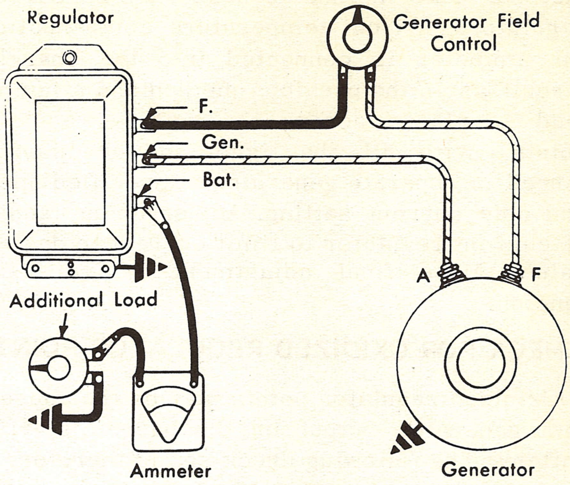
OPERATION: Regulators of the double contact type are similar to the unit just discussed, with the exception of the voltage regulator which is provided with two sets of points instead of one. Two sets of points are used in the voltage regulator to accommodate the high field current used in the generator.

The lower set of contacts limits the generator voltage at low speeds. Vibration of the lower contacts intermittently inserts resistance in the generator field circuit. This resistance is satisfactory for low speeds. When the speed is increased, the lower set of points can no longer control the voltage and the armature closes the upper set of points. A vibrating action takes place on the upper contacts to regulate the voltage at high speeds.



33-23. Checking cutout relay closing voltage.

The lower set of contacts is in series with the field circuit, and the upper set of contacts short out the generator field. The operation of the lower series set of contacts on the voltage regulator unit limits generator voltage, by inserting resistance in series with the generator field circuit. When this series will not control the generator voltage at the predetermined setting, the generator voltage increases slightly causing the upper set of contacts to operate. The upper set of contacts place a short circuit directly across the generator field circuit, limiting the voltage to a predetermined value.

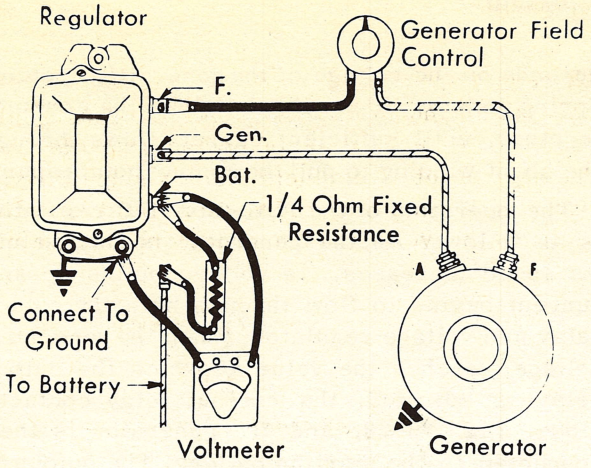


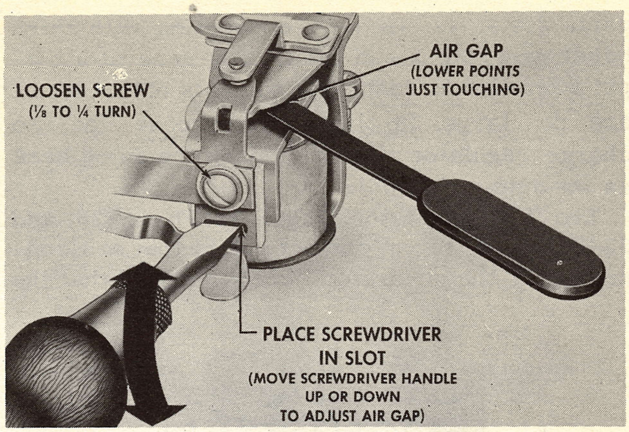
33-24. Checking current regulator current setting.

CUTOUT RELAY TESTS: Connect a voltmeter between the generator terminal of the regulator and the ground as shown in Fig. 33-23 and a 25-ohm, 25-watt rheostat that has an open position, between the field terminal and the field lead from the generator. Set the engine on fast idle and the rheostat turned to position of maximum resistance. Slowly turn out the resistance until the cutout relay points close and note the voltage. Set to specified voltage by turning adjusting screw on cutout relay.

Slowly turn rheostat to obtain specified amperage reading. Then slowly increase resistance, noting how far the ammeter will move below zero, before the relay opens up and returns the needle to zero. This reading is the opening amperage of the cutout relay, and it is the amount of reverse current discharged from the battery to generator that is required to open the points. If reverse current is between 1 and 6 amps., the cutout relay is operating normally. The only adjustment is the air gap which should be .020 in. Adjust by loosening the two screws in back of relay and raise or lower armature as required. Point opening should be .020 in.

CURRENT REGULATOR TEST: Connect a 1000-watt carbon pile resistor, ammeter and generator field control as shown in Fig. 33-24.




AIR GAP (LOWER POINTS JUST TOUCHING)
LOOSEN SCREW (1/8 TO 1/4 TURN)
PLACE SCREWDRIVER IN SLOT (MOVE SCREWDRIVER HANDLE UP OR DOWN TO ADJUST AIR GAP)

33-25. Left. Connections for checking voltage regulator adjustment of double contact regulator.
33-26. Right. Checking and adjusting voltage regulator air gap of double contact regulator.

Speed up engine to approximately 2000 r.p.m. and at the same time, add enough load to bring current regulator into operation. As speed of generator increases and additional load is added, ammeter will move up scale to a maximum reading. From this point, increasing or decreasing the load will lower the ammeter reading. Ammeter reading should be between 42 to 47 amps. on cars equipped with 45 amp. regulator and 32 to 37 amps. on cars equipped with 35 amp. regulators.

To adjust current setting, turn adjusting screw of current regulator clockwise to increase setting. Final setting should always be made by increasing spring tension. After each adjustment and before taking reading, replace regulator cover and cycle the generator.

To adjust air gap, push current regulator armature until contact points just close. The air gap should be .075 in.

VOLTAGE REGULATOR TESTS: Never ground generator field with regulator connected to generator. This will instantly burn up the upper set of contact points when the system is operated.

To check voltage regulator, make connections as shown in Fig. 33-25. Then with generator field control turned to position of minimum resistance, operate generator at a medium speed, or a higher speed so that regulator is operating on upper set of contacts. Operate at that speed for 15 minutes. Regulator cover must be in place. Cycle generator by turning generator field control to open position momentarily, then slowly decrease resistance. Regulator should be operating on upper contacts between specified voltages.

Increase generator field control slowly until regulator begins to operate on lower set of contact points. The lower set should operate at specified voltage below the upper set of contacts.

To adjust the voltage setting while operating on the upper set of points, turn the adjusting screw on regulator clockwise to increase voltage setting, using an Allen type wrench. Final setting should always be made when increasing the tension on spring.

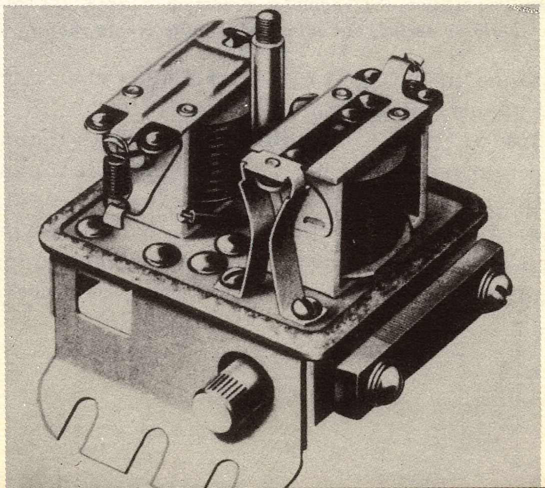
The difference in voltage between operation of the upper set of contacts and the lower contacts, is increased by slightly increasing air gap between armature and center of core, and decreased by slightly decreasing the air gap. This adjustment can be made while the regulator is operating as shown in Fig. 33-26. If it is found necessary to make this air gap adjustment, the voltage setting of both sets of contacts must be rechecked. Air gap should be measured with contact points just touching.

AUTO-LITE REGULATORS

TWO-CHARGE REGULATOR

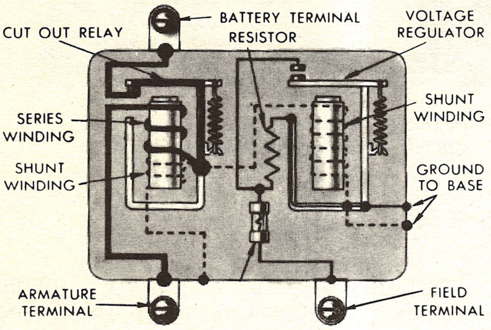
The Auto-Lite two charge regulator, Fig. 33-27, which is known as the T C in Auto-Lite

33-27. Auto-Lite two-charge regulator with cover removed. This unit includes a cut-out relay and a two-step voltage control. The voltage regulator contacts are closed when at rest and open when the winding is sufficiently energized by the circuit voltage.

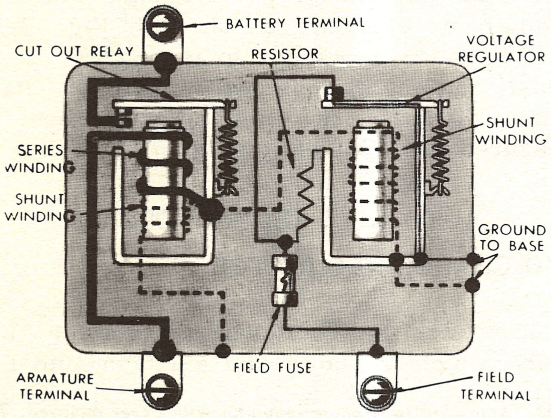


parts lists, is used in connection with third brush generators and reduces the generator output when the current requirements of the circuit are not large. In almost every case, the two charge regulator is mounted on the same base as the cutout relay.

The T C regulator, Figs. 33-27, 33-28, and 33-29 has a set of contact points that are connected in the generator field circuit so that the field is connected directly to the ground when the contacts are closed, Fig. 33-28. When the contacts are open, Fig. 33-29, a resistance is inserted in the field circuit. Inserting the resistance in the field circuit reduces the current and results in a lowered output.



33-28. When the contacts of the voltage regulator are open on the Auto-Lite two-charge regulator, a resistance is placed in series with the generator field circuit.



33-29. Wiring diagram of Auto-Lite two-charge regulator with contacts at rest. The heavy line is the series circuit, while the dotted line shows the regulator operating current. During the build-up period, the units and circuits are as shown.

One of the T C regulator contacts is mounted on a stationary bridge while the other is mounted on the movable magnetic armature. An electromagnet with many turns of fine wire is shunted across the generator output. The amount of magnetism developed in the electromagnet therefore depends on the voltage of the generating system. Spring tension is provided to hold the contacts together, until sufficient current flows through the shunt winding to pull the contact points apart.

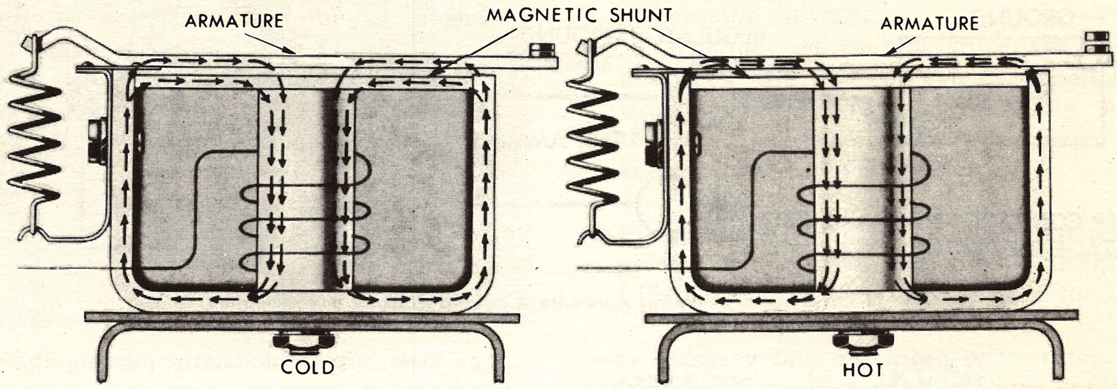
The operation of the Auto-Lite T C regulator is as follows: As the generator is started and its speed increases, its voltage builds up and current begins to flow through both the cutout relay and voltage regulator. When the generated voltage reaches the value at which the cutout relay is adjusted, the cut-out relay contacts close, Fig. 33-28, and the generator is then connected to the starting battery. The output of the generator will then continue to rise as determined by the speed of the generator and the position of the third brush.

The voltage increases with the current and the amount of increase is dependent on the condition of the battery and the electrical load. If the battery requires charging or if the load is heavy, the voltage will not rise very far above the value at which the cut-out relay is adjusted. However, if the battery is fully charged, and the external load is light, or if there is excessive resistance in the charging circuit, the voltage rises very rapidly. When the voltage reaches the value for which the voltage regulator is adjusted, the magnet in the voltage regulator overcomes the spring tension and pulls down the armature, opening the contact points, Fig. 33-28. This inserts the resistance in the field circuit, which reduces the output by approximately 50 per cent. The generator voltage is therefore reduced.

The voltage regulator contacts will remain open until additional load is placed on the circuit and causes the voltage to drop to a predetermined value. As a result the electromagnet will no longer be able to hold the armature down, so that the contact points will close, Fig. 33-29, and the field resistance will be shorted out of the circuit, thereby permitting the generator to return to its maximum charging rate.

In Auto-Lite regulators, the effect of heat on the resistance and operating characteristics of regulator windings is compensated for by the use of a nickel-iron magnetic by-pass on the voltage regulator unit. This by-passes some of the magnetic flux when the unit is cold, Fig. 33-30, and allows the majority of the flux to act on the armature when the unit is hot. As a result, this compensation permits the regulator to operate at a higher voltage when it is cold and a lower voltage when it is hot. This is necessary as a higher voltage is needed to charge a battery when its internal resistance is increased by low temperatures.

Most Auto-Lite two charge regulators have a fuse mounted on the base. This is connected in the generator field circuit and protects the field against excessive field current, which would happen if an open circuit occurs in the charging circuit.


ARMATURE
MAGNETIC SHUNT
ARMATURE
COLD
HOT

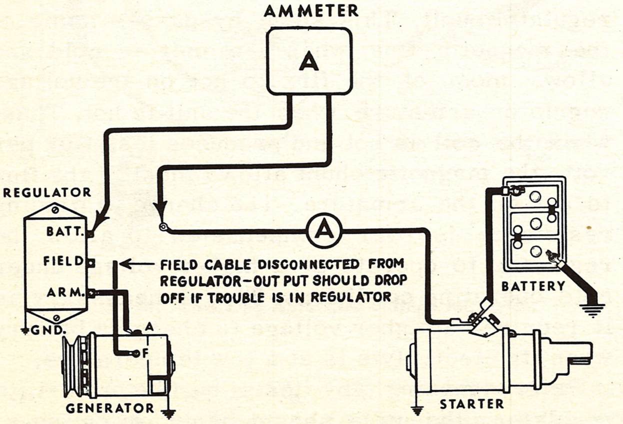
33-30. Details of magnetic shunt used on most Auto-Lite regulators. The magnetic shunt bridges the top of the yoke just below the armature and when cold, by-passes some of the magnetism so that a higher voltage is needed to operate the armature. As the shunt becomes heated, it loses its magnetic properties and all of the magnetic lines must act on the armature, in that way reducing the voltage necessary to produce enough magnetism to pull the armature down and open the contacts.

TESTING TWO-CHARGE REGULATOR

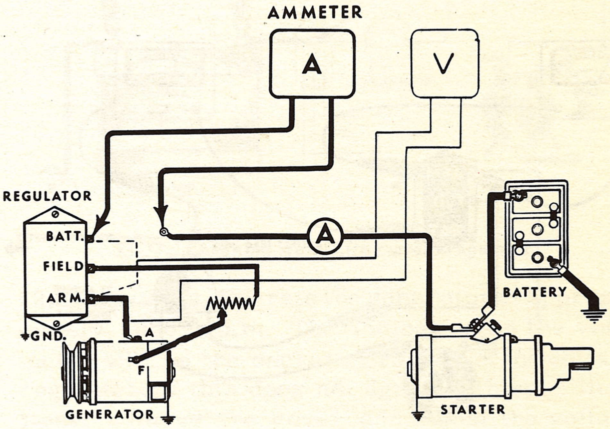
A quick test on a two charge regulator is to connect an ammeter in series with the lead from the battery and disconnect the field lead, Fig. 33-31. If the regulator is defective the output should drop off.

A more satisfactory test of the Auto-Lite two charge regulator is to connect a variable resistance between the regulator F terminal and the generator field lead, Fig. 33-32. Connect an ammeter between the B terminal and the lead removed from the terminal. A voltmeter must also be connected across the A terminal and the base of the regulator. Then with the generator and regulator at operating temperature and the regulator cover in place, adjust the variable resistance so that the voltage is as low as possible, then increase the voltage slowly, noting its value at which the cut-out relay points close. Adjust the closing voltage to the specified amount by bending the lower spring hanger. Be sure to replace the regulator cover before checking the setting.

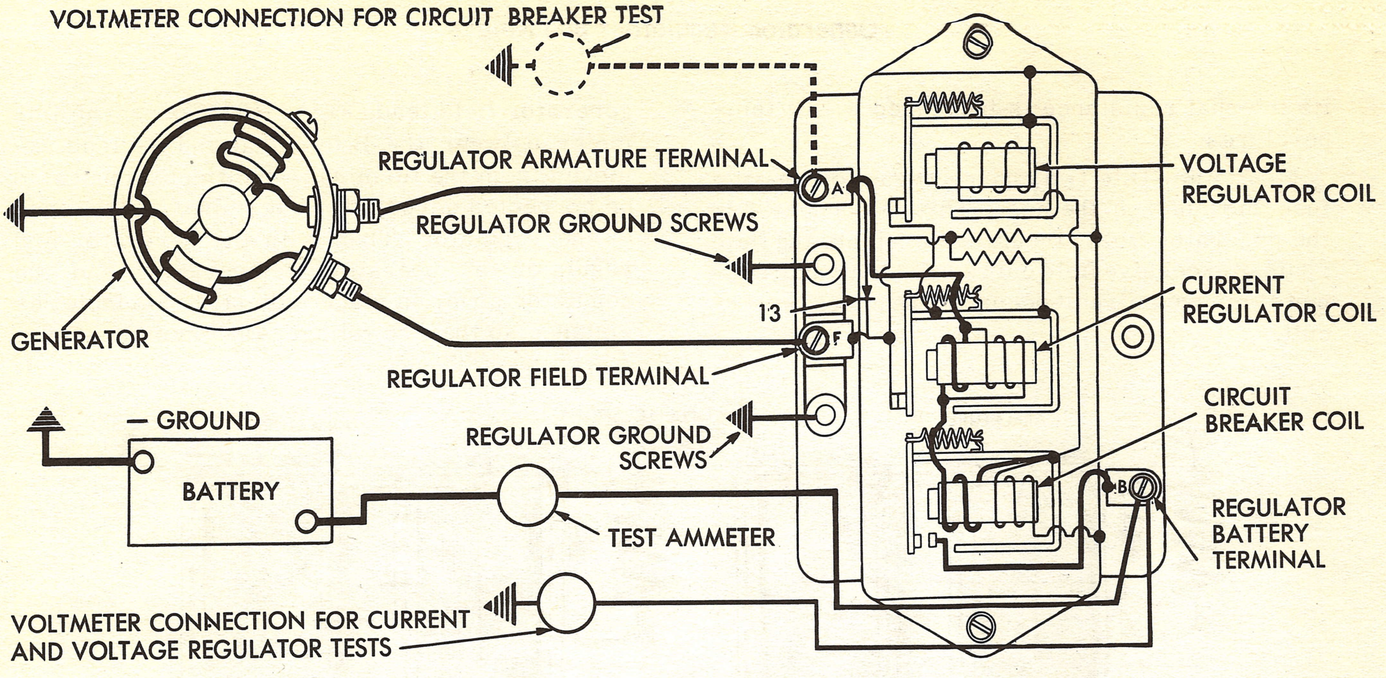
To set the voltage regulator of the two charge regulator, the voltmeter must be connected across the B terminal and the base of


AMMETER
A
REGULATOR
BATT.
FIELD
ARM.
GND.
FIELD CABLE DISCONNECTED FROM REGULATOR—OUT PUT SHOULD DROP OFF IF TROUBLE IS IN REGULATOR
A
A
F
BATTERY
GENERATOR
STARTER

33-31. A quick test of the Auto-Lite two-charge regulator is to disconnect the field lead. Then if the output drops, the regulator is defective.

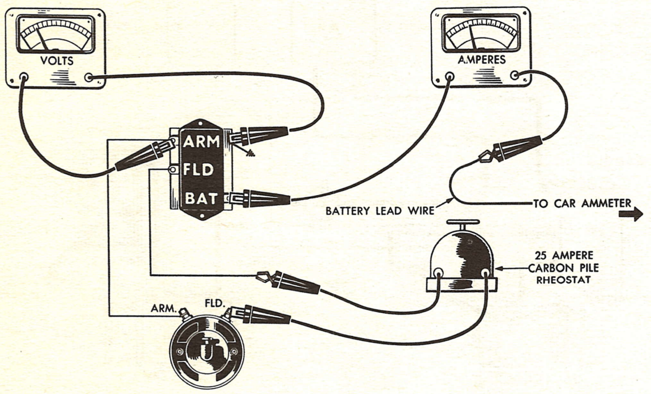

AMMETER
A
V
REGULATOR
BATT.
FIELD
ARM.
GND.
A
A
F
BATTERY
GENERATOR
STARTER

33-32. Connections for testing an Auto-Lite two-charge regulator on the car. Connect the regulator, generator, battery and meters as shown when checking the cut-out relay opening and closing. To check the voltage regulator, change the voltmeter connection from the regulator (A) terminal to the regulator (B) terminal.


VOLTMETER CONNECTION FOR CIRCUIT BREAKER TEST
REGULATOR ARMATURE TERMINAL
A
REGULATOR GROUND SCREWS
13
F
REGULATOR FIELD TERMINAL
GENERATOR
— GROUND
BATTERY
REGULATOR GROUND SCREWS
TEST AMMETER
VOLTMETER CONNECTION FOR CURRENT AND VOLTAGE REGULATOR TESTS
VOLTAGE REGULATOR COIL
CURRENT REGULATOR COIL
CIRCUIT BREAKER COIL
B
REGULATOR BATTERY TERMINAL

33-33. Diagram of typical Auto-Lite A circuit generator and regulator.

the regulator. The ammeter and variable resistance are connected the same as when checking the cut-out relay. First increase the generated voltage slowly until the contact points of the cutout relay close. Continue to increase the voltage slowly until the regulator contacts open. Then decrease the voltage slowly until the contacts close. The opening and closing voltages must be in accordance with those specified for that particular unit.


VOLTS
AMPERES
ARM
FLD
BAT
BATTERY LEAD WIRE
TO CAR AMMETER
25 AMPERE CARBON PILE RHEOSTAT
ARM.
FLD.

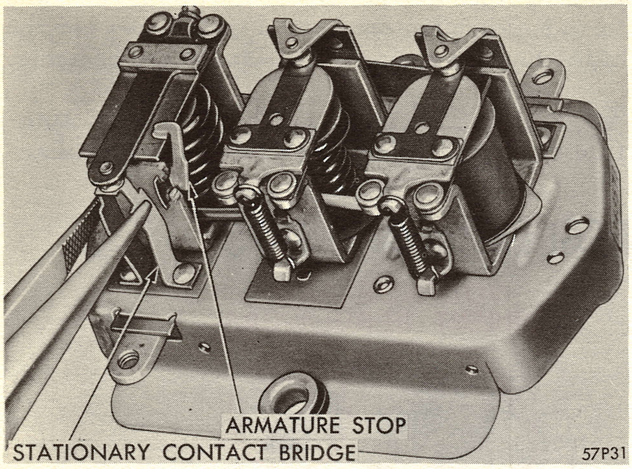
33-34. Diagram of connections when checking circuit breaker or cutout relay.

AUTO-LITE THREE UNIT REGULATOR

While both Delco-Remy and Auto-Lite use the A circuit for the generator and regulator system, there are some detailed differences. As will be noted in the diagram shown in Fig. 33-33 of the Auto-Lite system, the current regulator is provided with both a series and shunt winding, whereas the current regulator used in most Delco-Remy systems has only a series winding. In addition there is a difference in terminology. On the Auto-Lite unit, Fig. 33-33, the regulator terminal which is connected to the generator is marked A or ARM with the latter designation plainly embossed on the cover of the unit. Delco-Remy calls this same terminal "Gen" Another difference is in the location of the terminals, with Auto-Lite placing the battery terminal on one side of the regulator and the armature and field connections on the other.

Another and major difference is in the type of temperature compensation. To correct for the effects of heat on the operating characteristics of the regulator windings, Auto-Lite makes use of a nickel-iron magnetic by-pass on the voltage regulator unit. This shunt by-passes some of the magnetic flux when the unit is cold and allows most of the flux to act on the voltage regulator armature when the unit is hot. Thus, when the coil is hot and produces less flux per volt, the magnetic shunt allows most of the flux to act on the armature. The change in winding resistance is over compensated to allow the regulator to operate at a higher voltage under cold operating conditions. This is necessary as it requires a higher voltage to charge a battery when its electrolyte is at a low temperature.

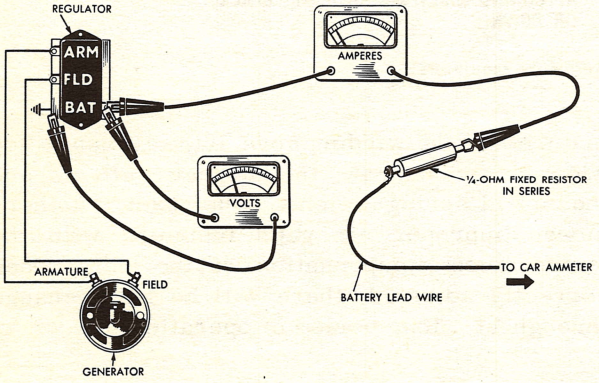
Before making any tests on the Auto-Lite regulator, the units should be in operation at least 15 minutes in order to bring it to operating temperature. Final tests must be made with the cover in place and with the unit mounted in the same position it occupies on the vehicle. Each time an adjustment is made and the cover replaced, the generator should be cycled. Auto-Lite suggests two ways of cycling the generator.


ARMATURE STOP
STATIONARY CONTACT BRIDGE
57P31

33-35. Adjusting contact gap on cutout relay.

1. Vary generator speed, drop speed to zero and return to test r.p.m.
2. Varying generator voltage. Use field rheostat to drop voltage to near zero, and return to regulated amount by gradually turning rheostat to "all out."

CUTOUT RELAY TEST: Connect instruments as shown in Fig. 33-34. Operate generator at approximately 1500 to 2000 r.p.m. Turn rheostat to increase generator voltage. At the instant the cutout relay contacts close, the voltmeter will show a slight dip. The highest voltage before the "dip" occurs is the closing voltage of the cutout relay.


REGULATOR
ARM
FLD
BAT
AMPERES
VOLTS
¼-OHM FIXED RESISTOR IN SERIES
ARMATURE
FIELD
TO CAR AMMETER
BATTERY LEAD WIRE
GENERATOR

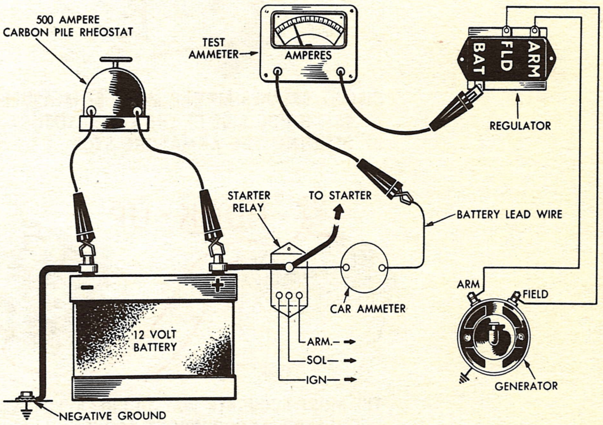
33-36. Checking Auto-Lite voltage regulator.

To check the opening of the cutout relay, use same connections shown in Fig. 33-34. Turn the field rheostat until the ammeter reads 10 to 15 amps., then reduce the amperes slowly with the field rheostat. Observe the discharge amperage just before the contacts open. If the opening and closing of the cutout relay points do not check with specifications, remove the cover and make adjustments.

To adjust the closing voltage, change the spring tension by bending the lower spring hanger, Fig. 33-1. Increasing tension raises the closing voltage.

To adjust the opening amperage, increase or decrease the contact gap by bending the stationary contact bridge, Fig. 33-35. Decreasing the gap lowers the opening amperage. Be sure to keep the points in alignment.

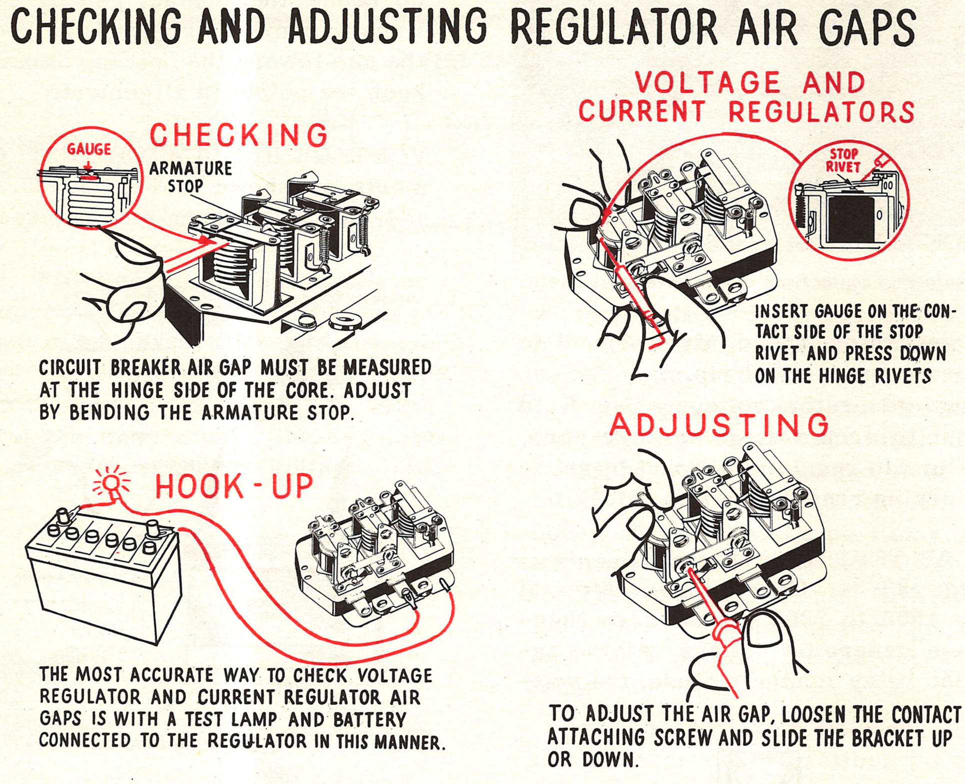
VOLTAGE REGULATOR TEST: Connect instruments as shown in Fig. 33-36. In this test the 1/4-ohm resistance may be used for both 6 and 12-v. systems. Operate the generator at approximately 3000 r.p.m. The indication on the voltmeter will be the operating voltage of the voltage regulator. If this does not agree with specifications, remove the cover and adjust the voltage unit spring tension by bending the lower spring hanger. Increasing the tension, raises the operating voltage. Replace cover quickly, and cycle the generator.


500 AMPERE CARBON PILE RHEOSTAT
TEST AMMETER
AMPERES
ARM
FLD
BAT
REGULATOR
STARTER RELAY
TO STARTER
BATTERY LEAD WIRE
ARM
FIELD
CAR AMMETER
12 VOLT BATTERY
ARM.
SOL
IGN
GENERATOR
NEGATIVE GROUND

33-37. Checking Auto-Lite current regulator.

CURRENT REGULATOR TEST: To test the operating current of the regulator, make the connections shown in Fig. 33-37. Operate the generator at approximately 3000 r.p.m. Adjust the carbon pile until maximum amperage is obtained on the ammeter. This is the output at which the regulator is adjusted. If this does not agree with specifications, remove the cover and adjust the current regulator spring tension by bending the lower spring hanger, Fig. 33-1. Increasing the tension raises the operating current. If a carbon pile is not available, the battery may be partly discharged by operating the starting motor 15 seconds at a time. Then start the engine and operate the generator at approximately 3000 r.p.m. and note the ammeter reading. This will be the operating current of the current regulator.

SERVICING AUTO-LITE CONTACTS: On Auto-Lite regulators, the circuit breaker or cutout relay contacts are both made of coin silver. The upper contact and lower contact of both voltage and current regulators are made of dissimilar metals. These are basically two different alloys of silver. It is very important that these contacts be installed in their proper relation according to the grounding of the system in which they are used. If the wrong contacts are installed, or if a regulator of the opposite polarity is used, transfer of metal and arcing of the contacts will be greatly increased, resulting in shorter contact life. Armatures and stationary contact brackets of all positive ground units are cadmium plated. Armature and stationary contact brackets of negative units are copper plated.


CHECKING AND ADJUSTING REGULATOR AIR GAPS

CIRCUIT BREAKER AIR GAP MUST BE MEASURED AT THE HINGE SIDE OF THE CORE. ADJUST BY BENDING THE ARMATURE STOP.

INSERT GAUGE ON THE CONTACT SIDE OF THE STOP RIVET AND PRESS DOWN ON THE HINGE RIVETS

THE MOST ACCURATE WAY TO CHECK VOLTAGE REGULATOR AND CURRENT REGULATOR AIR GAPS IS WITH A TEST LAMP AND BATTERY CONNECTED TO THE REGULATOR IN THIS MANNER.

TO ADJUST THE AIR GAP, LOOSEN THE CONTACT ATTACHING SCREW AND SLIDE THE BRACKET UP OR DOWN.

33-38. Adjusting air gaps on Auto-Lite regulators.

To clean Auto-Lite regulator contacts, use a No. 6 American Swiss cut equalling file. Filing must be done parallel with the armature. Do not use emery cloth or sandpaper. After filing, the contacts should be cleaned by placing a narrow strip of linen tape between the contacts, then saturate the tape with carbon tetrachloride, drawing the wet portion of the tape back and forth between the contacts. Finally a dry portion of the tape should be used between the contacts.

AIR GAP ADJUSTMENT: The air gap on Auto-Lite regulators is the air space between the armature and the winding core. If the air gap is too wide or too narrow, the magnetic effects and the spiral spring action will be upset. Furthermore, improper air gaps interfere with the temperature compensation of the units. Once correctly adjusted, there will be little change throughout a long period of operation.

CIRCUIT BREAKER: The circuit breaker air gap is checked with the contacts open. A two step flat gauge is used. The smaller end of the specified gauge should just slide between the core and armature, and the large portion of the gauge should not go in. Adjustment is made by bending the brass armature stop on top of the unit, Fig. 33-38.

VOLTAGE AND CURRENT REGULATOR: The air gap on these units is checked at the instant the contacts barely separate. The most accurate way to check the voltage and current regulator air gaps is to connect a test lamp in series with the current and voltage regulator contacts, Fig. 33-38.

With the regulator at rest, both sets of contacts are closed and the lamp should light. A special pin-type gauge having two specified dimensions is used for checking. With the smaller gauge inserted between the armature and the core on the contact side of the stop rivet, press down on the two hinge rivets. This causes the armature to move down against the gauge and the contact spring will follow. The contact points should open slightly as indicated by the lamp dimming or going out. Next insert the larger gauge, and press down on the hinge rivets. The light should burn normally, indicating that the contacts are still closed.

If the air gap is out of adjustment, loosen the contact adjusting screw, Fig. 33-38, and slide the bracket up or down as required. Be sure to keep the contacts aligned to insure maximum contact life.

The contact assemblies on both the Auto-Lite voltage and current regulators are the same, and the air gaps are checked in the same manner. After adjusting the air gaps and before making any electrical tests, the regulator base should be struck sharply on the bench several times to make sure all parts are settled in place. Be sure to strike the base equally so as not to damage the mounting lugs or resistors.

Ambient Temperature °F.	Voltage Regulation Setting (Volts)				
	Standard Regulator (Ford and Bosch)	40 amp. Low Cut In (Autolite)	30 amp. Low Cut In, 50 amp. and 60 amp. (Bosch)		60 amp. (Ford)
			Lower Stage	Upper Stage	
25	15.1-15.9	14.3-15.2	14.4	15.1	15.5
35	15.0-15.8	14.3-15.2	14.3	15.0	15.4
45	14.9-15.7	14.3-15.1	14.3	15.0	15.3
55	14.8-15.6	14.3-15.0	14.2	14.9	15.2
65	14.7-15.5	14.3-14.9	14.2	14.8	15.1
75	14.6-15.4	14.2-14.9	14.1	14.8	15.0
85	14.5-15.3	14.1-14.8	14.0	14.7	14.9
95	14.3-15.1	14.1-14.7	14.0	14.7	14.8
105	14.2-15.0	14.0-14.7	13.9	14.6	14.6
115	14.1-14.9	14.0-14.6	13.9	14.5	14.5
125	13.9-14.7	13.9-14.5	13.8	14.5	14.4
135	13.8-14.6	13.8-14.4	13.7	14.4	14.3
145	13.6-14.4	13.8-14.4	13.7	14.4	14.2

33-39. Ford voltage regulator temperature compensation chart.

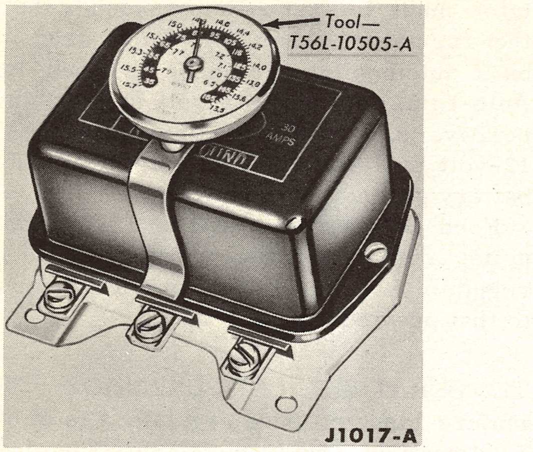
FORD REGULATORS

With the exception of a double contact Delco-Remy regulator used on some Ford cars equipped with air conditioning, all Ford regulators are of the B circuit type which ground the field inside the generator. The double contact regulator made by Delco-Remy grounds the field in the regulator. Other regulators used on Ford built automobiles are made by Ford, Bosch or Auto-Lite. Former six-volt systems have the positive side of the battery grounded, while 12-volt systems have the negative side of the battery grounded.

Ford regulators consist of the familiar three units: cutout, current regulator and voltage regulator. The units operate in a manner similar to that previously described.

TEMPERATURE COMPENSATION: The armature hinge of these regulators is of bi-metal construction, and is built into armature hinge. The temperature sensitivity of the bi-metal causes the voltage regulator setting to change according to temperature. Therefore it is necessary to establish a normal or stabilized regulator operating temperature to coincide with the specified setting. The temperature of the surrounding air for this setting is 70 to 80 deg. F. The regulator temperature for this or any other setting is defined as the temperature of the regulator after one-half hour of operation on the car, or after the regulator has been heated until it becomes stabilized, Fig. 33-39.

For correct voltage regulator adjustment, first be sure that the regulator has reached normal operating temperature; then make the voltage adjustment setting coincide with the temperature of the surrounding air, which is the under hood temperature. Specifications are shown in Fig. 33-39. To measure the temperature, a special thermometer, Fig. 33-40, is clamped to the case of the regulator. When a regulator is being checked on a work bench, the temperature would be the room temperature. The procedure is to clip the thermometer to the regulator case and mount a small fan 15 in. from the regulator. The fan will provide sufficient air flow to assure stabilization of the regulator at the temperature indicated by the thermometer.



33-40. *Special thermometer attached to Ford regulator for checking temperature.*

The following tests apply to all B circuit regulators.

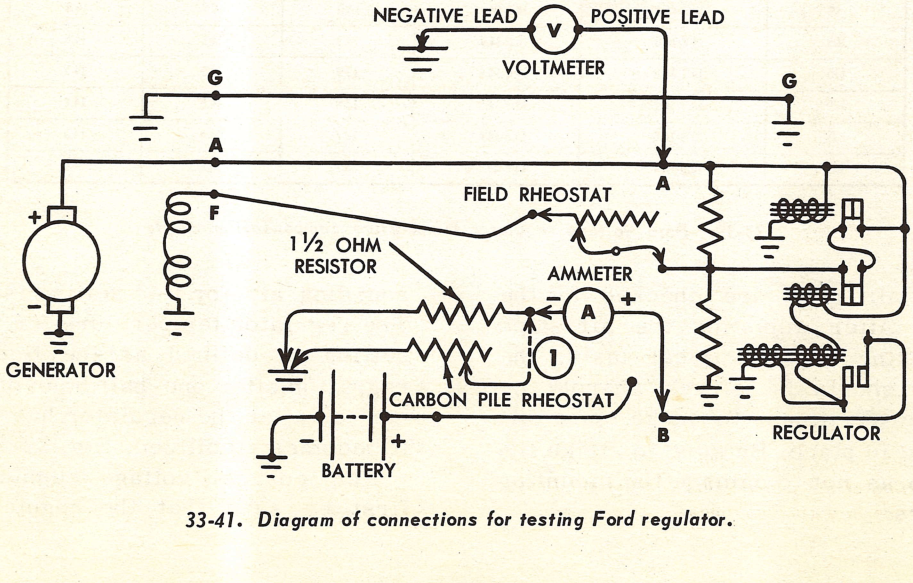
CUTOUT TEST: Start the engine and run it at approximately 1500 r.p.m. Make connections as shown in Fig. 33-41 and Fig. 33-42. Decrease the resistance in the field circuit, and the voltage output of the generator as indicated by the voltmeter, will increase until the cutout closes. The cutout closing will be indicated by a rise of the ammeter needle and a dip of the voltmeter needle. The maximum voltage at the time the voltmeter needle dips will be the closing voltage of the cutout.

To adjust the cut-in voltage, bend the adjusting arm, Fig. 33-43, upward to increase the voltage on Ford-built units. On the Bosch unit, Fig. 33-44, bend the cutout spring adjusting arm upward to decrease the cut-in voltage.

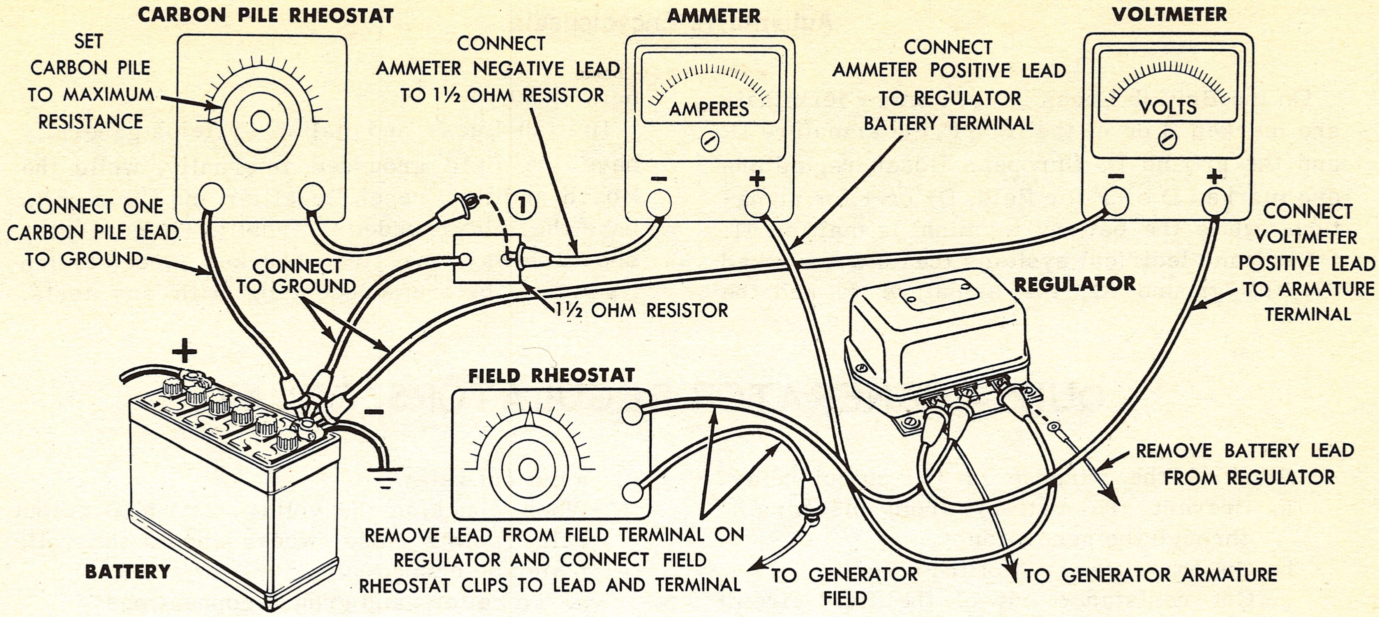
VOLTAGE REGULATOR TEST: Make the connections as shown in Fig. 33-41 and Fig. 33-42. Reduce resistance in field circuit to zero. The ammeter should show an approximate 10 amp. load. Read the voltage regulation on the voltmeter scale. Speed the engine momentarily to see if voltage remains regulated. If the regulator voltage is not within the limits set by the specifications for the ambient temperature, compute the difference as a positive or negative correction. Remove the regulator cover, and make a new voltage regulator test. Adjust the new setting up or down by the amount of the correction computed.

To increase the voltage setting, increase the spring tension by bending the adjustment arm upward, Fig. 33-43. On the Bosch heavy-duty unit, Fig. 33-44, bend the voltage limiting spring upward to decrease the voltage.

CURRENT REGULATOR TEST: Connect the carbon pile rheostat across the 1-1/2 ohm resistor (6v. systems use 3/4 ohm resistor), Fig. 33-41



33-41. *Diagram of connections for testing Ford regulator.*

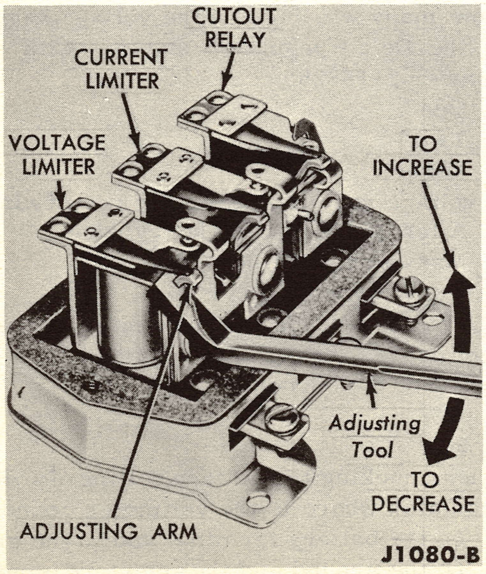

CARBON PILE RHEOSTAT
SET CARBON PILE TO MAXIMUM RESISTANCE
CONNECT ONE CARBON PILE LEAD TO GROUND
CONNECT AMMETER NEGATIVE LEAD TO 1½ OHM RESISTOR
AMMETER
AMPERES
–
+
CONNECT AMMETER POSITIVE LEAD TO REGULATOR BATTERY TERMINAL
VOLTMETER
VOLTS
–
+
CONNECT VOLTMETER POSITIVE LEAD TO ARMATURE TERMINAL
①
CONNECT TO GROUND
1½ OHM RESISTOR
REGULATOR
+
–
BATTERY
FIELD RHEOSTAT
REMOVE BATTERY LEAD FROM REGULATOR
REMOVE LEAD FROM FIELD TERMINAL ON REGULATOR AND CONNECT FIELD RHEOSTAT CLIPS TO LEAD AND TERMINAL
TO GENERATOR FIELD
TO GENERATOR ARMATURE

33-42. Instruments and connections used in testing Ford regulators.

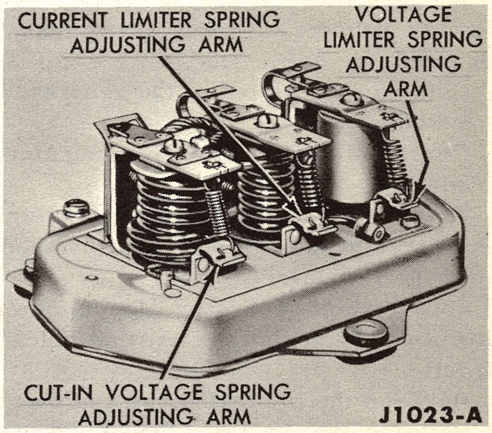
and Fig. 33-42. With the engine speed at 1500 r.p.m. slowly decrease the resistance of the rheostat until the voltmeter reading drops to 13v., (6v. systems 6.5v.). The ammeter will indicate the setting of the current regulator.

Remove all test leads except the voltmeter leads. Install the battery and field leads on the regulator terminals. Run the engine at 1500 r.p.m., and read the voltage regulation under battery load on the voltmeter. The voltmeter will usually be low when the engine is first started, because the battery is partly discharged. After a few minutes of operation, the voltage will rise to the original value.

If the current limit is less than specified, increase the spring tension by bending the current regulator adjusting arm upward, Fig. 33-43.


CUTOUT RELAY
CURRENT LIMITER
VOLTAGE LIMITER
TO INCREASE
Adjusting Tool
TO DECREASE
ADJUSTING ARM
J1080-B

33-43. Adjusting the voltage regulator setting on the Ford standard regulator. The setting of the cutout relay and current limiter is made in a similar manner.


CURRENT LIMITER SPRING ADJUSTING ARM
VOLTAGE LIMITER SPRING ADJUSTING ARM
CUT-IN VOLTAGE SPRING ADJUSTING ARM
J1023-A

33-44. Illustrating the adjustments on the Bosch heavy duty regulator.

FOREIGN CAR REGULATORS

The regulators used on imported cars are basically the same as those used domestically. However, there is considerable confusion because of the many different systems of lettering used to identify the different connections. In addition, some regulators will have five and more terminals. In such cases the additional terminals are connections for various accessories and form a sort of terminal block. These additional terminals are usually marked A-1, A-2, etc.

On the British Lucas units, battery terminals are marked B or A, the field F, the armature D, and the ground D. European Bosch regulators are marked D or F for field, D+ or + for armature, while the battery terminal is marked 51. On Italian electrical systems the field is marked 67, the ground 31, the armature 51 and the battery 30.

British Lucas and Italian systems generally have the field grounded internally, while the Bosch and the French Ducellier and Cibie units have the field grounded externally. The generator should always be first checked to determine its type, before proceeding with any tests.

QUIZ - GENERATOR REGULATORS, RELAYS

1-What is the purpose of the cutout relay?
  a. Prevent the battery from discharging through the generator
  b. Cut the battery out of the circuit
  c. Cut resistance out of the field circuit

2-What is the purpose of the voltage regulator?
  a. Maintain a constant charging rate
  b. Prevent the circuit voltage from exceeding a predetermined value
  c. Prevent battery from discharging through the generator

3-What is the purpose of the current regulator?
  a. Protect the generator from overload
  b. Maintain a constant charging rate
  c. Prevent battery from discharging through the generator

4-When the battery is low in charge, what does the regulator do?
  a. Cuts resistance out of the generator field circuit
  b. Cuts resistance into the generator field circuit
  c. Cuts resistance into the armature circuit

5-Why is temperature compensation needed on a voltage regulator?

6-In an A-circuit generator, the voltage regulator inserts resistance at what point in the circuit?
  a. Between the field windings and the ground
  b. Between the insulated brush and the field
  c. Between the armature and the ground

7-In a B-circuit generator, the voltage regulator inserts resistance at what point in the circuit?
  a. Between the field windings and the ground
  b. Between the insulated brush and the field
  c. Between the field and the ground

8-A cut out relay has two windings. One of a few turns of heavy wire and the other of many turns of very fine wire. Where is the winding of heavy wire connected?
  a. In series with the charging circuit
  b. Shunted across the generator
  c. In series with the ground

9-What three adjustments should be made on a cut out relay?

10-When checking the voltage at which cutout relay points close, where should the voltmeter be connected?
  a. To battery and ground connections
  b. To generator and ground connections
  c. To generator and battery connections

11-A step voltage control unit is usually used on what type of generator?
  a. A circuit
  b. B circuit
  c. Third brush

12-If the charging rate remains high, when the F lead is disconnected from a voltage control unit, what is indicated?
  a. Generator is in good condition
  b. Voltage control unit is defective
  c. Generator field circuit is grounded

13-The two unit regulator is usually used with what type of generator?
  a. A circuit generator
  b. B circuit generator
  c. Third brush generator

14-How many windings on the voltage regulator of the Delco regulator starting with serial number 1118825?
  a. One
  b. Two
  c. Three

15-A voltage regulator has what kind of winding?
  a. A few turns of very heavy wire
  b. Many turns of fine wire
  c. Many turns of heavy wire

16-In a current regulator, how much of the current passes through the winding?
  a. All of the current
  b. 75%
  c. 50%

17-When checking the voltage setting of a voltage regulator where is the voltmeter connected?
  a. To the battery terminal and to the ground
  b. To the ground and the armature terminals
  c. To the field and battery terminals

18-When checking the voltage setting of a voltage regulator, where is the fixed resistance

connected?
  a. In series with the battery terminal
  b. In series with the ground
  c. In series with the field

19-When checking the setting of a current regulator, should the voltage regulator be operating?

20-Why are double contact regulators used on some installations?

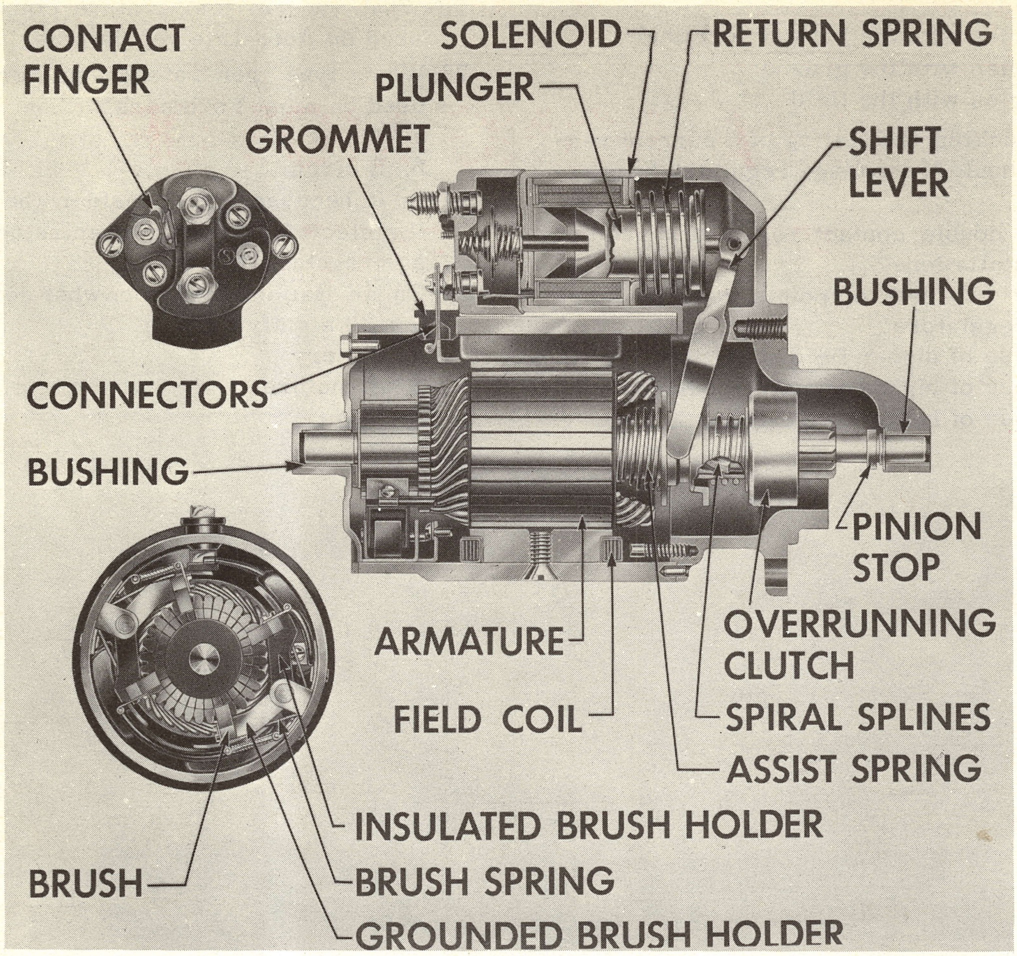
21-Why are two sets of points used on some voltage regulators?
  a. Because of higher field current
  b. Because of higher armature current
  c. Because of heavy duty battery

22-What type of temperature compensation is used on Auto-Lite regulators?

23-What type generator-regulator circuit is used on most Ford cars?
  a. A circuit
  b. B circuit

24-Is it necessary to consider the polarity of the electrical system when selecting a voltage regulator?

25-On an Italian regulator, what does the number 30 signify?
  a. Battery
  b. Armature
  c. Field

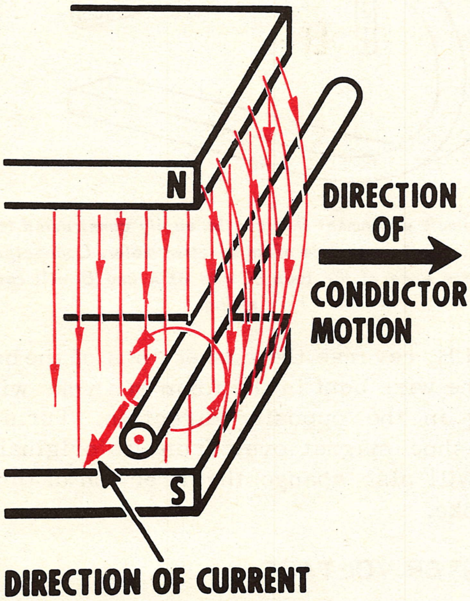

CONTACT FINGER
SOLENOID
RETURN SPRING
PLUNGER
GROMMET
SHIFT LEVER
BUSHING
CONNECTORS
BUSHING
PINION STOP
OVERRUNNING CLUTCH
ARMATURE
FIELD COIL
SPIRAL SPLINES
ASSIST SPRING
INSULATED BRUSH HOLDER
BRUSH
BRUSH SPRING
GROUNDED BRUSH HOLDER

34-1. Sectional and end view of starting motor with solenoid and overruning clutch type of engagement.

CRANKING MOTOR FUNDAMENTALS

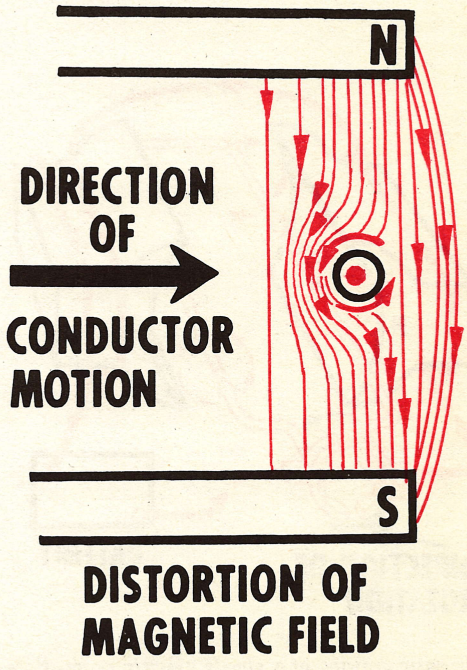
The cranking motor, Fig. 34-1, is an electric motor designed specifically for cranking internal combustion engines, at speeds sufficient to permit starting.

The electric motor such as is used for cranking an internal combustion engine operates on the principle that a current-carrying conductor tends to move from a strong magnetic field to a weak magnetic field. In Fig. 34-2, is shown a magnetic field from a permanent magnet in which a single conductor is placed. Current is flowing through the conductor toward the reader. It will be seen by the right hand rule, that the flow of current in the conductor causes a magnetic field to circle the conductor, as shown by the circular arrows, which in this case is in the counterclockwise direction. As the magnetic field of the permanent magnet combines with that of the current-carrying conductor, a resultant force is exerted on the conductor. This force will tend to move the conductor toward the right.



34-2. When a current-carrying conductor is placed in a magnetic field, it will tend to move in direction indicated.

The manner in which the magnetic fields of the permanent magnet, and the current-carrying conductor react is shown in Fig. 34-3. The circular magnetic field surrounding the conductor opposes the permanent magnetic field on the right side of the conductor, which in turn creates a weaker magnetic field. At the same time, the two fields combine on the left side of the conductor to create a stronger magnetic field. In effect, there is more magnetism on the left side of conductor and less on the right side.



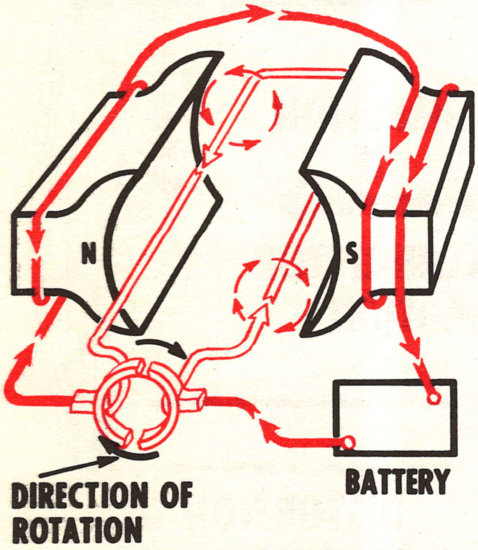
34-3. Note how the magnetic field surrounding the current-carrying conductor is distorted.

The magnetic field is distorted in that manner, and as the lines of force tend to straighten out, they exert a thrust toward the right on the conductor.

ROTARY MOTION

To see how this side thrust is converted into rotary motion, the conductor is bent into a loop as shown in Fig. 34-4. The rotating part is known as the armature. It will be noted that the ends of the loop are connected to two semicircular brass bars called the commutator. The magnetic field of the two magnetic poles is created by two electromagnets. Current for the electromagnets, which in this case are called field coils, is provided by a battery. Tracing the circuit from the battery, it will be seen that the armature coil and the field coils are connected in series. In other words, when the circuit is completed, current flows from the battery, through the armature winding, through the field coils and back to the battery.

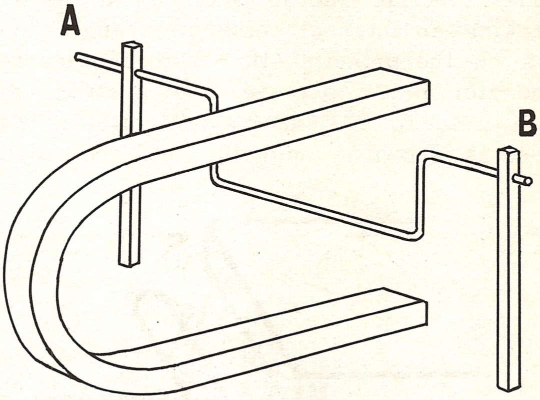
The current flowing through the field coils produces a strong magnetic field which flows from the north pole (on the left) to the south pole on the right. At the same time current flowing through the armature coil produces a circular magnetic field to surround the conductor as shown by the arrows, Fig. 34-4. This circular magnetic field is in a clockwise direction on the right hand conductor of the armature, and counterclockwise around the left conductor. Note that the current in the left hand side of the armature coil is flowing toward the reader, which is the same direction as shown in Fig. 34-2. This results in an upward thrust on the conductor. As the current is flowing in the opposite direction in the other side of the armature coil, the thrust will be in the opposite direction, or downward.



34-4. Schematic drawing of a simple electric motor. Note the direction of current flow and the field around the conductor.

The combination of the two thrusts causes the armature to rotate. This rotation will continue, for as the armature coil passes the vertical position, the commutator, which rotates with the armature, will automatically connect the armature coil so the current will continue to flow away from the reader in the right hand, and toward the reader in the left hand coil.

The tendency for a current-carrying coil to move when placed in a magnetic field can be easily demonstrated by means of a permanent magnet, a battery and some wire as shown in Fig. 34-5. After connecting the battery to points A and B, reverse the connections of the battery, and the wire bent in the form of a yoke will then swing in the opposite direction. Turning the horseshoe magnet over from its original position will also change the direction of thrust on the yoke.



34-5. Simple equipment that can be easily constructed to demonstrate the basic principle of an electric motor. Connecting a battery to the ends of the loop of wire at A and B will cause it to swing.

COUNTER VOLTAGE

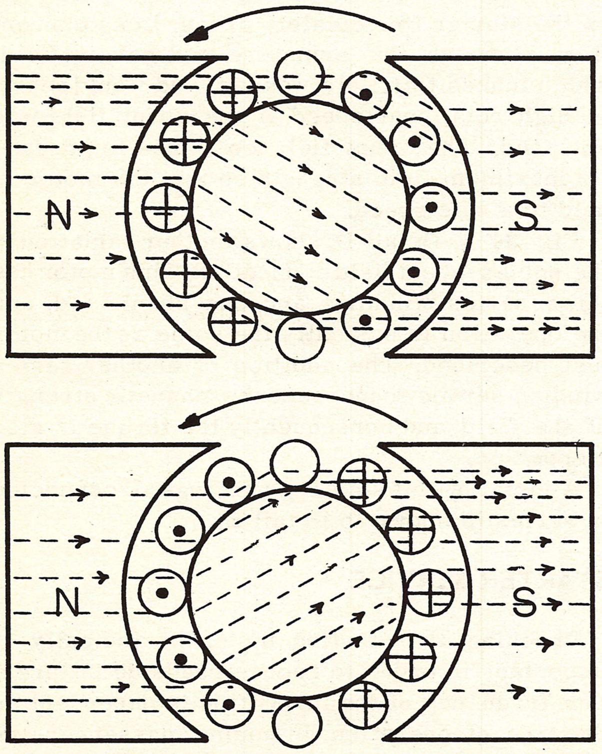
As was pointed out in the unit on the Fundamentals of Electricity, when any conductor is moved through a magnetic field, a voltage will be induced in the conductor. This condition also occurs in a motor, when the conductor is being supplied with current. However, the voltage induced in the conductor (by virtue of the fact that it is cutting magnetic lines of force) will be in the opposite direction to the voltage that is being supplied to the motor. Such voltage is known as a back voltage, or counter electromotive force.

EFFECT OF COUNTER E.M.F.

The effect of the counter E.M.F. is to limit the current in the armature, and as the speed of the armature increases, the counter E.M.F. also increases. As it is opposed to the voltage applied to the motor, it has the effect of decreasing the effective voltage. As a result, the voltage that is forcing current through the armature is the difference between the applied voltage, and the counter E.M.F. Actually this counter E.M.F. is the same voltage which that armature would develop, if it were operated as a generator.

ARMATURE REACTION

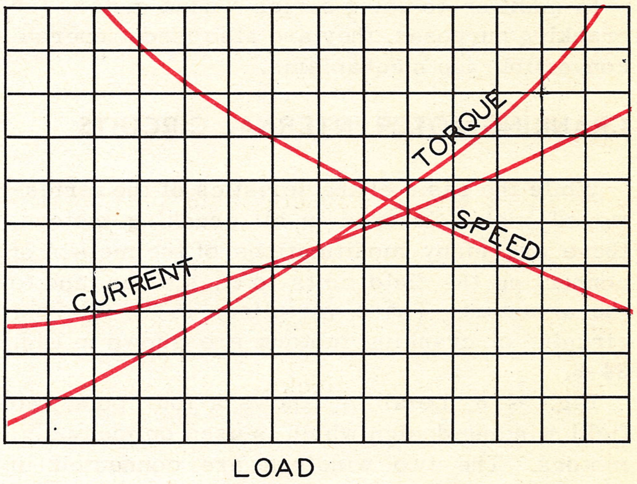
Armature reaction in motors is similar to armature reaction in generators. However, the current in a motor armature is opposite to that of a generator rotating in the same direction, Fig. 34-6. As a result, the armature reaction in a motor is similar in principle to that of a generator, which was explained in detail in the unit dealing with the fundamentals of generators. The difference lies in the fact that the current in the armature, moving in the opposite direction, will magnetize the armature core in the opposite direction. Since the direction of the field current is the same in both machines, the reaction of the two magnetic fields in each case, will be in opposite directions. A comparison of the armature reactions of a motor and a generator is shown in Fig. 34-6.



34-6. *The field distortion caused by armature reaction on a motor is shown in the top drawing, and in a generator below.*

SPEED AND TORQUE CHARACTERISTICS

A reason for using a series-wound motor for cranking internal combustion engines is that it has extremely high torque. Torque varies as the strength of the magnetic field and the current in the armature. With the armature and field coils in series, any increase in current will produce an increase in the strength of the field. As the load on the motor increases, the current through the fields and armature will also increase. As a result, the torque will keep increasing as the load increases. This is shown in Fig. 34-7.



34-7. *Current, torque and speed characteristics of series motor.*

The speed of a series-wound motor will vary with the load. For any given load which a certain series motor is driving there will be a certain definite speed. With heavy loads, series-wound motors will operate at a relatively slow speed. With a light load, such motors will operate at very high speeds. The explanation is as follows:

Any armature always tends to operate at such a speed that the voltage used in overcoming its resistance, plus the counter E.M.F., will be equal to the voltage being applied to the motor. At heavy loads the current, and the voltage consumed in overcoming the internal resistance, will be large. Consequently, the armature will not have to rotate at a very high speed to produce the required counter E.M.F. to equal the applied voltage. However, under light loads, the motor speeds up, inducing a higher counter E.M.F. and decreasing the current through the field and armature coils. This weakens the strength of the field, causing a further increase in armature speed, which again decreases the counter E.M.F.

With no load, the speed of a series-wound motor will continue to increase to such an extent that centrifugal force will destroy the armature. Series-wound motors as used for cranking internal combustion engines should therefore never be operated without a load except under controlled conditions.

In addition to using series-wound motors for cranking purposes, they are also used to operate convertible top mechanisms.

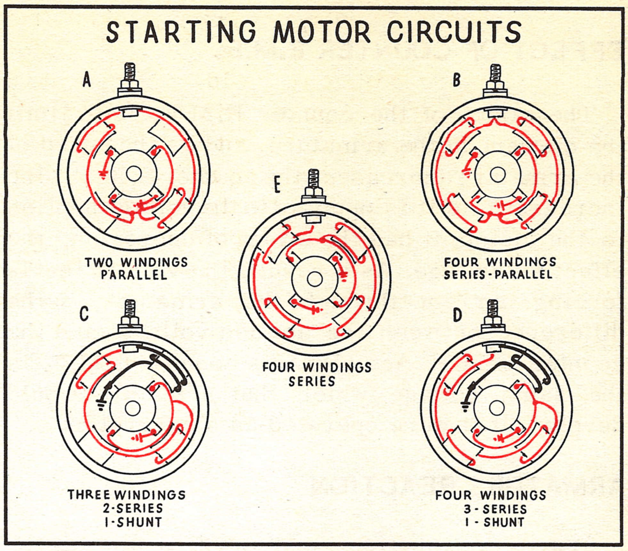
CRANKING MOTOR INTERNAL CIRCUITS

While the basic characteristics of the series-wound motor is used in all cranking motors, there are many modifications of the method of connecting the field coils to each other and to the armature. These variations in the internal circuits of cranking motors are shown in Fig. 34-8.

Fig. 34-8, Detail A, shows a four pole, two field winding design which is used on many 6 v. motors. The two windings are connected in parallel to each other. and in series with the armature. This permits a high current and results in a strong magnetic field. The current divides and equal amounts pass through each field winding. All of the current then passes through the armature, with the result that high cranking torque is produced. The two poles which have no winding serve to complete the magnetic circuits.

In Fig. 34-8, Detail B, the motor has four field windings on four poles and is connected in series parallel. The total current divides through the parallel field circuits, then combines and goes through the armature. This type motor is used primarily on 6 v. systems.

A variation of the two winding motor is shown in Fig. 34-8, Detail C. This is a series-shunt connection, and is used largely on 12 v. starting systems. The two heavy windings are connected in series, and carry current to the armature. The third field winding is a shunt coil, and is connected between the starting motor terminal and ground. The shunt coil has two purposes, first to assist the series coils to build up and maintain a high magnetic field, and second to prevent excessive motor speed and noise, when the armature is not subjected to cranking load.


STARTING MOTOR CIRCUITS
A
TWO WINDINGS PARALLEL
B
FOUR WINDINGS SERIES-PARALLEL
E
FOUR WINDINGS SERIES
C
THREE WINDINGS 2-SERIES 1-SHUNT
D
FOUR WINDINGS 3-SERIES 1-SHUNT

34-8. Five different starting motor circuits.

When the motor is cranking the engine, heavy current flows through the series windings to form the magnetic field. The ampere turns in the shunt field provide additional strength under this condition. When the engine starts, the load on the starter immediately drops. Less current flows through the armature and series field, which makes this field weaker, and would result in high rotational speed if the shunt field was not used. The shunt field continues to produce its maximum field strength so that the motor is held to a safe speed.

Fig. 34-8, Detail D, shows another variation in the series-shunt field connection. This motor has three series windings and one shunt field, and the operation is basically the same as the motor just described. The addition of another series winding serves to increase the magnetic strength of the field and consequently the torque is also stepped up.

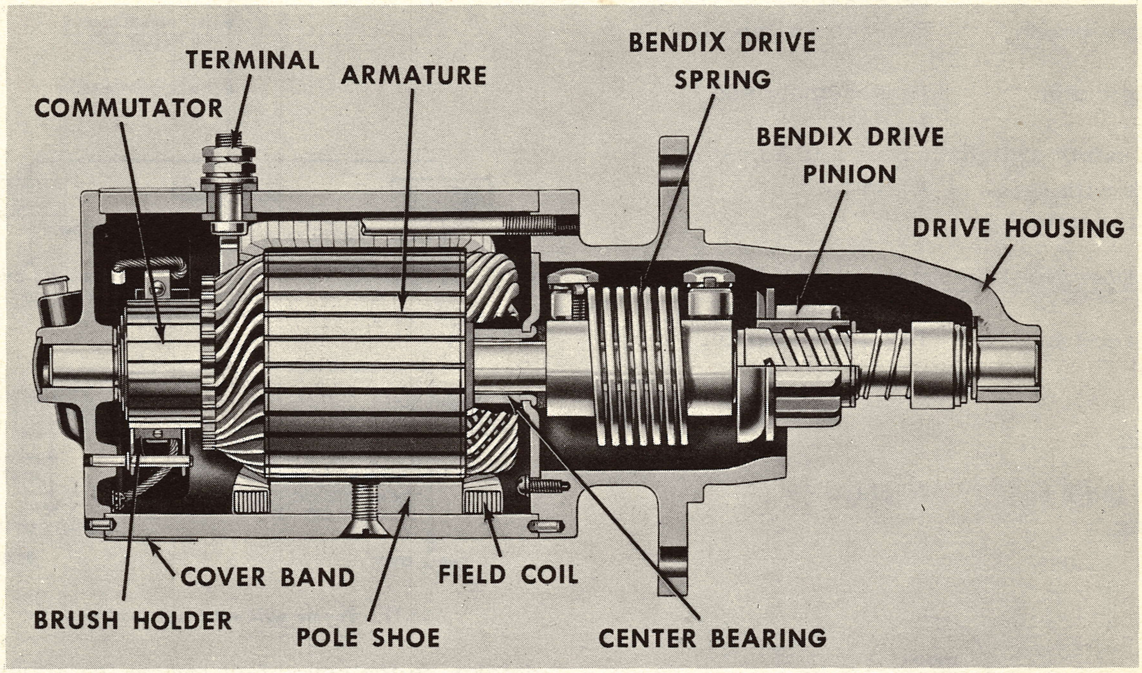
A motor with four field windings all connected in series is shown in Detail E.

STARTER SERVICE

Checking the starting motor periodically is important in order to reduce roadside failures. The frequency of the inspection is dependent on the type of operation. In normal passenger car service, the motor should be inspected every 10,000 miles of operation. In door-to-door delivery service or other forms of operation, a more frequent inspection is desirable. Batteries and cables should be inspected every 5,000 miles.

To inspect the starting motor, the cover band should be removed, and the condition of the commutator and brushes noted. If the commutator is dirty it should be cleaned with a strip of No. 00

sandpaper, which is held against the commutator while the armature is rotating. To prevent the motor from overheating, it should not be operated for more than 30 seconds at a time. If the commutator is rough, pitted, or out-of-round, or if the mica is high, the starting motor should be disassembled and the commutator reconditioned in a lathe. Mica on starting motor commutators should be undercut 1/32 in. If there are spots of solder on the interior surface of the cover band or starter housing, it indicates that the motor has overheated due to excessively long periods of cranking. This may cause open circuits at the commutator riser bars and consequent failure. Each time an open-circuited bar passes under a brush, severe arcing will occur so that the commutator bar will be badly pitted.



34-9. Standard Bendix drive mounted on Delco-Remy starting motor.

Brushes should make good clean contact with the commutator and should have the specified spring tension. Brushes should also have free movement in the brush holders and if worn more than one half their length, they should be replaced.

The starting motor must be securely bolted to the engine and the drive must operate freely. If the motor is fitted with oilers, it should be oiled with a few drops of light engine oil.

At approximately 25,000 mile intervals, the starting motor should be completely disassembled, cleaned, inspected, and tested. The armature and field windings should not be cleaned in any grease dissolving solution nor by any high temperature grease removing solution as that would damage the insulation.

If the starting motor is equipped with a Bendix type drive, Fig. 34-9, the drive should be cleaned with kerosene and lubricated with a trace of light engine oil on the spiral sleeve. Excessive oiling must be avoided.

The overrunning clutch type drive must never be cleaned with high temperature or grease dissolving solution. The drive pinion on the overrunning clutch should turn freely in the overrunning direction and should not slip in the driving direction.

TROUBLE SHOOTING

Starter Cranks Engine Slowly
(See Fig. 34-10).

Cause:	Remedy:
Low battery	Recharge or replace battery.
Excess resistance in cranking circuit	Check for excess resistance at cable and connections with meters.
Engine	Check for tight engine bearings, pistons, rings, etc.
Cranking motor	Disassemble and check for bent armature, or armature dragging on field poles.

Starter Inoperative

(See Fig. 34-11)

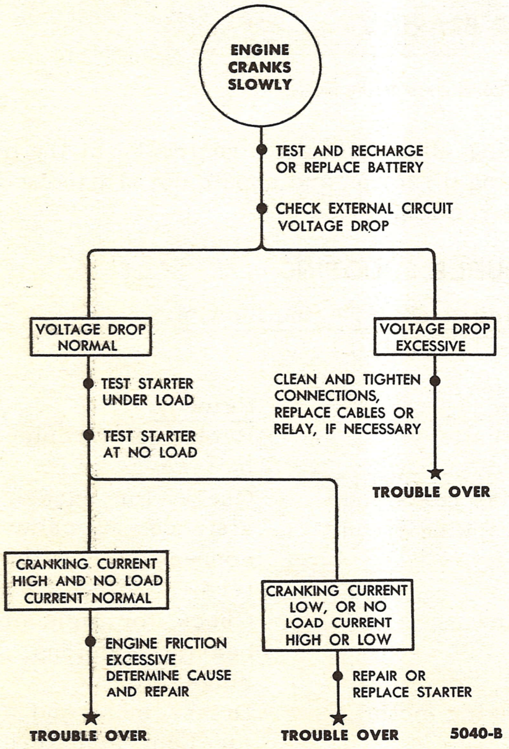
Battery dead	Replace battery.
Open starter circuit	Check cable connections, starter switch, solenoid, wiring.
Inoperative solenoid	Check plunger for free movement and contact points for closing. Replace solenoid if necessary.
Instrument panel switch	Replace switch.
Cranking motor	Disassemble and Inspect.
Neutral safety switch (on cars with automatic transmissions)	Check and adjust or replace.

Starter Does Not Disengage

Short circuit in solenoid	Replace solenoid.

Windings

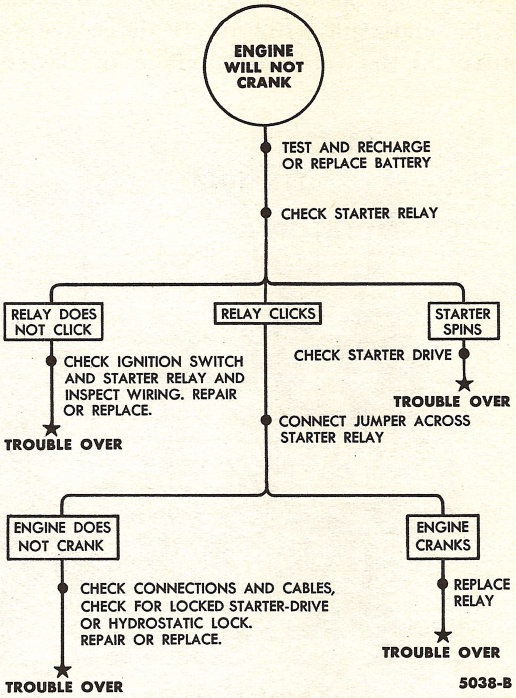
Chipped teeth on ring gear	Replace.


ENGINE CRANKS SLOWLY
TEST AND RECHARGE OR REPLACE BATTERY
CHECK EXTERNAL CIRCUIT VOLTAGE DROP
VOLTAGE DROP NORMAL
VOLTAGE DROP EXCESSIVE
TEST STARTER UNDER LOAD
TEST STARTER AT NO LOAD
CLEAN AND TIGHTEN CONNECTIONS, REPLACE CABLES OR RELAY, IF NECESSARY
TROUBLE OVER
CRANKING CURRENT HIGH AND NO LOAD CURRENT NORMAL
CRANKING CURRENT LOW, OR NO LOAD CURRENT HIGH OR LOW
ENGINE FRICTION EXCESSIVE DETERMINE CAUSE AND REPAIR
REPAIR OR REPLACE STARTER
TROUBLE OVER
TROUBLE OVER
5040-B

34-10. Starting motor circuit trouble shooting road map.

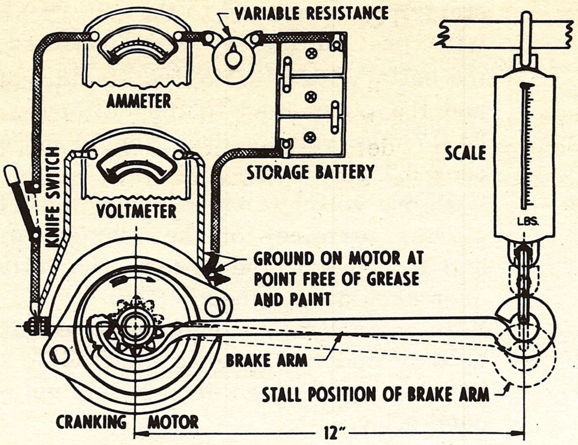
STARTER MOTOR TESTS

There are a number of tests that are made on the starting motor, and the starting motor system, in order to determine its operating condition. The stall torque test is made to determine the pound feet torque the starter will develop, and the amperage draw at the specified voltage. The no-load test is made to determine how fast the armature will revolve, and the current draw at the specified voltage. Other tests determine the condition of the various windings of the motor.


ENGINE WILL NOT CRANK
TEST AND RECHARGE OR REPLACE BATTERY
CHECK STARTER RELAY
RELAY DOES NOT CLICK
RELAY CLICKS
STARTER SPINS
CHECK IGNITION SWITCH AND STARTER RELAY AND INSPECT WIRING. REPAIR OR REPLACE.
CHECK STARTER DRIVE
TROUBLE OVER
TROUBLE OVER
CONNECT JUMPER ACROSS STARTER RELAY
ENGINE DOES NOT CRANK
ENGINE CRANKS
CHECK CONNECTIONS AND CABLES, CHECK FOR LOCKED STARTER-DRIVE OR HYDROSTATIC LOCK. REPAIR OR REPLACE.
REPLACE RELAY
TROUBLE OVER
TROUBLE OVER
5038-B

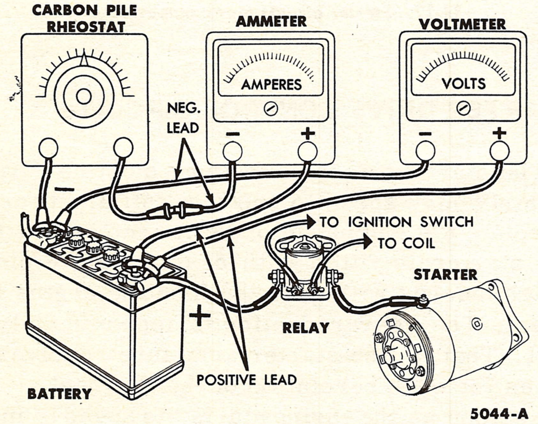
34-11. Engine will not crank road map.

Stall Torque Test: To make a stall torque test, Fig. 34-12, equipment must be provided to absorb and measure the torque. A simple tester consists of an arm, one end of which is clamped to the starter drive pinion, and the other end is fastened to a spring scale. The length of the arm from the center of the drive pinion to the spring scale, should be 12 in. A high current-carrying resistance and ammeter, are connected in series with the starter and a battery. The battery should consist of one 6 v. battery more than the normal voltage of the battery. Then with the voltmeter connected across the starter terminals, the circuit is closed and the resistance adjusted, until the specified voltage is obtained at the starter. The current draw and the pound feet torque are then noted.


VARIABLE RESISTANCE
AMMETER
STORAGE BATTERY
SCALE
LBS.
KNIFE SWITCH
VOLTMETER
GROUND ON MOTOR AT POINT FREE OF GREASE AND PAINT
BRAKE ARM
STALL POSITION OF BRAKE ARM
CRANKING MOTOR
12"

34-12. Diagrammatic for starting motor torque tester.

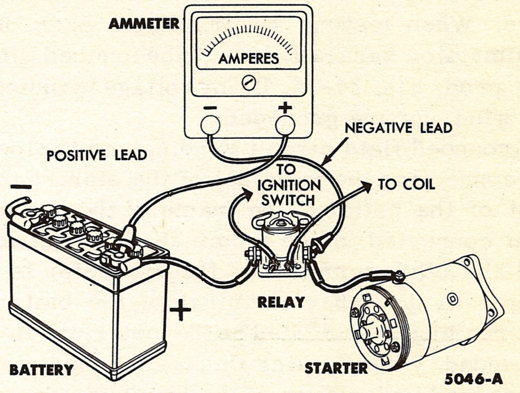
Starter Load Test: Connect the test equipment as shown in Fig. 34-13. Make sure no current is flowing through the ammeter and heavy duty carbon pile rheostat portion of the circuit (rheostat at maximum resistance). Crank the engine with the ignition off. If necessary, pull high tension lead from ignition coil. Note the exact reading of the voltmeter. Stop cranking the engine, and reduce the resistance of the carbon pile rheostat until the voltmeter indicates the same voltage as that obtained while the starter cranked the engine. The ammeter will indicate the starter draw under load. This reading should correspond with specified value, (usually 200 to 300 amp.). Engine must be at normal operating temperature.


CARBON PILE RHEOSTAT
AMMETER
AMPERES
VOLTMETER
VOLTS
NEG. LEAD
TO IGNITION SWITCH
TO COIL
STARTER
RELAY
BATTERY
POSITIVE LEAD
5044-A

34-13. Connections for making starter load test.

Starter No-load Test: This test will disclose such faults as open or shorted windings, rubbing armature and bent armature shaft. The starter can be tested at no-load, either on or off the engine. To make the test on the engine, the engine must be running at idle speed, to prevent the starter drive from engaging the flywheel. With the engine idling, make the connections shown in Fig. 34-14. The no-load draw as shown on the ammeter should correspond to the specified value, usually 100 to 175 amps.

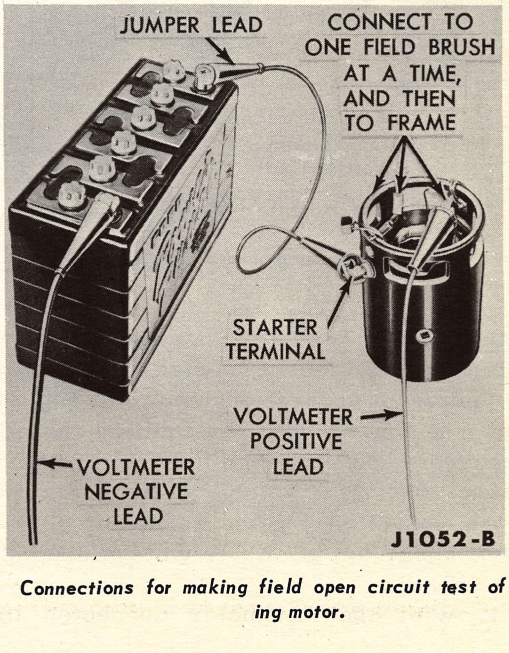
To make this test on the bench, connect the starter, battery and ammeter in series. The starter will then be running at no-load, and the ammeter will indicate the no-load current.


AMMETER
AMPERES
NEGATIVE LEAD
POSITIVE LEAD
TO IGNITION SWITCH
TO COIL
RELAY
BATTERY
STARTER
5046-A

34-14. Connections for making starter no-load test.

Armature and Field Open Circuit Test: An open circuit armature may sometimes be detected by examining the commutator for evidence of burning. The spot burned on the commutator, is caused by an arc formed every time the commutator segment connected to the open circuited winding passes under a brush.

An open circuit test of the field can be made by means of a test lamp, Fig. 32-12, or by connecting a voltmeter and battery as shown in Fig. 34-15. As starters have several windings,

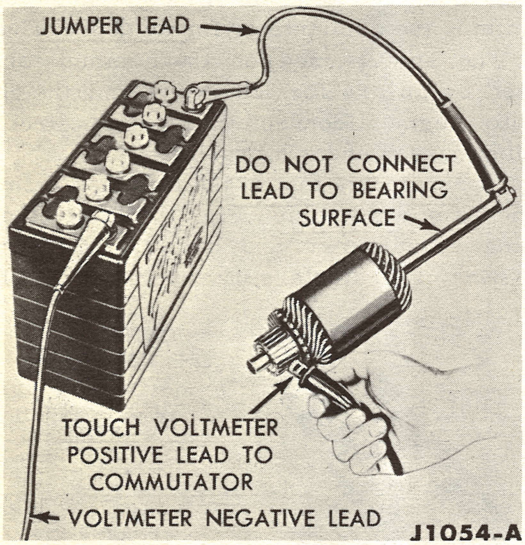

JUMPER LEAD
CONNECT TO ONE FIELD BRUSH AT A TIME, AND THEN TO FRAME
STARTER TERMINAL
VOLTMETER POSITIVE LEAD
VOLTMETER NEGATIVE LEAD
J1052-B

34-15. Connections for making field open circuit test of starting motor.

it will be necessary to check each winding separately. If no reading is obtained on the voltmeter, the winding is open, and will have to be repaired or replaced.

Armature and Field Grounded Circuit Test: This test can be made with the test lamp, Fig. 32-12, or by using a voltmeter. This test will determine if the winding insulation has failed, permitting a conductor to touch the starter frame or armature core. When testing the armature, each of the commutator bars will have to be touched with the test prod, Fig. 34-16. If any voltage is indicated, the windings are grounded.

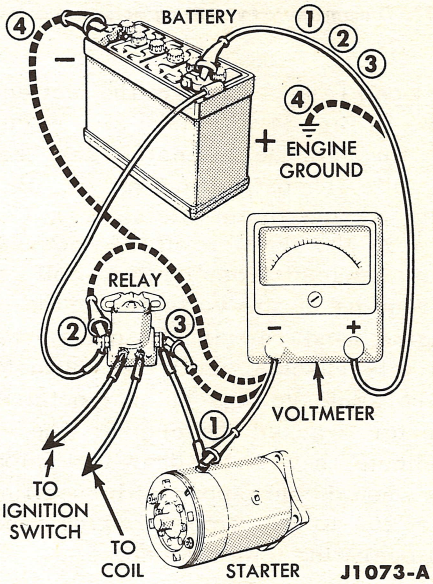
Grounded field circuit windings can be located by connecting the terminal of the starter to one post of the battery; the frame of the starter is then connected to one terminal of the voltmeter and the other terminal of the voltmeter is connected to the other terminal of the battery. If any reading is indicated on the meter, the field is grounded. When making this test, place a piece of cardboard under each of the brushes, to insulate them from the armature, if the armature is in place. Or if the armature has been removed keep the brushes away from the frame.


JUMPER LEAD
DO NOT CONNECT LEAD TO BEARING SURFACE
TOUCH VOLTMETER POSITIVE LEAD TO COMMUTATOR
VOLTMETER NEGATIVE LEAD
J1054-A

34-16. Armature grounded circuit test.

Starter Circuit Test: Excessive resistance in the starter circuit, can be located by means of the test equipment connections shown in Fig. 34-17. Crank the engine with the ignition turned off. If necessary, pull the high tension lead from the ignition coil. The voltage drop in the circuit will be indicated by the voltmeter (0 to 1 v. range). Maximum allowable voltage drop should be as follows:

1. With the voltmeter connected to the starter terminal and to the battery 0.5 v.
2. With one voltmeter lead connected to the battery terminal of the starter relay and the other lead to the battery, Fig. 34-17, the voltage drop should not exceed 0.1 v.
3. With one voltmeter lead connected to the starter terminal of the starter relay and the other to the battery, the voltage drop should not exceed 0.3 v.
4. With one voltmeter lead connected to the battery and the other connected to the ground, the voltage drop should not exceed 0.1 v.



34-17. Starter circuit test connections.

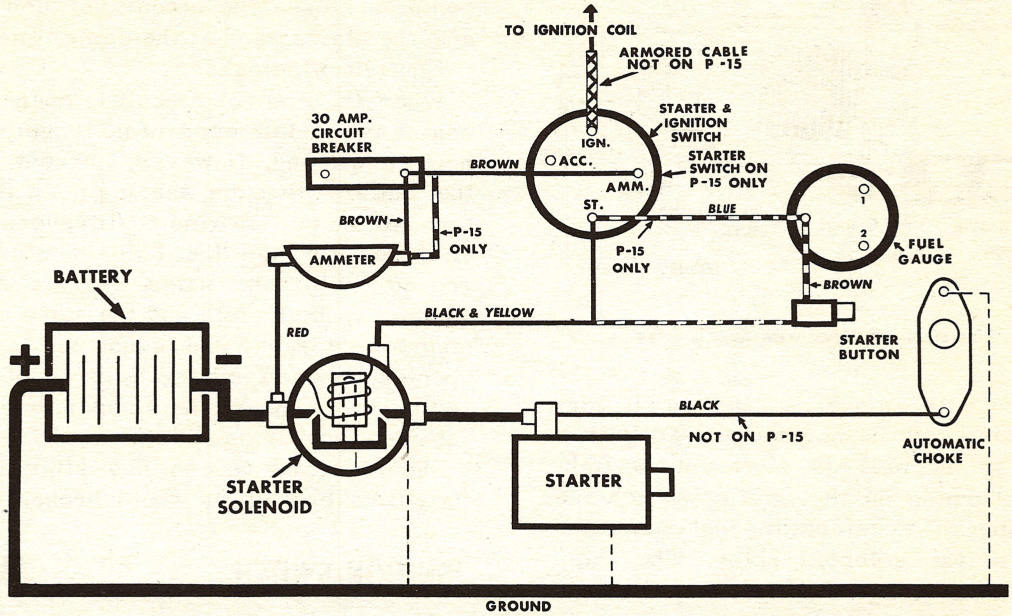
STARTER DRIVE CONTROL CIRCUITS

The starting motor armature must revolve at a fairly high speed to produce sufficient torque to rotate the engine. In order to accomplish this, the starter is fitted with a small drive pinion which meshes with gear teeth on the engine flywheel. The gear reduction is approximately 15 to 1. That is, the starter armature revolves 15 times for each revolution of the flywheel.

As soon as the engine starts, its speed is much greater than the cranking speed, and if the starter drive pinion remained engaged with the flywheel, the starter speed would be excessive. For example, if the engine speed was 1,000 r.p.m., the starter speed would be 15 times as great or 15,000 r.p.m. Such a speed would ruin the armature and to prevent this, various mechanisms have been developed which permit the gears to mesh during the cranking period but which demesh the gears as soon as the engine is started.

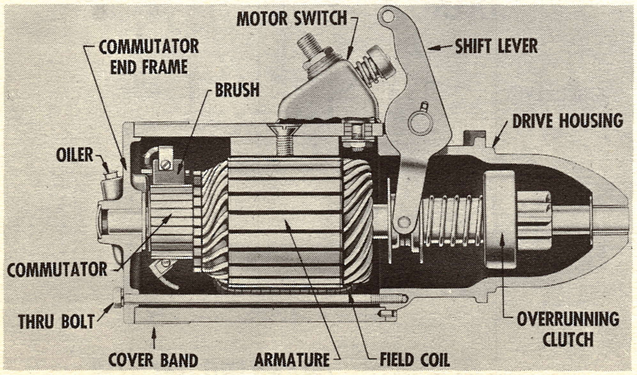
STARTING MOTOR CONTROL CIRCUITS

There are various types of controls used with starting motors and typical circuits are shown in Fig. 34-18 and Fig. 34-26. The simplest control is a pedal or switch which when operated connects the starter directly to the battery so that cranking takes place. On overrunning clutch, Fig. 34-19, or Dyer drive starters, the pedal not only operates the starter switch but it also shifts the drive pinion into mesh with the flywheel ring gear.

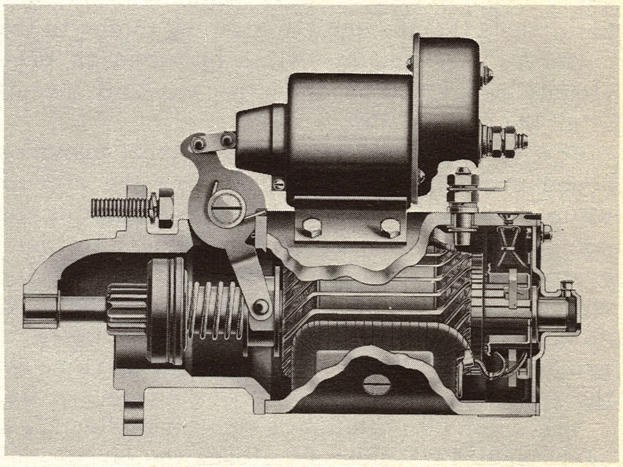

TO IGNITION COIL
ARMORED CABLE NOT ON P-15
STARTER & IGNITION SWITCH
IGN.
ACC.
AMM.
ST.
STARTER SWITCH ON P-15 ONLY
BLUE
30 AMP. CIRCUIT BREAKER
BROWN
BROWN
P-15 ONLY
AMMETER
P-15 ONLY
1
2
FUEL GAUGE
BROWN
BATTERY
+
−
RED
BLACK & YELLOW
STARTER BUTTON
AUTOMATIC CHOKE
BLACK
NOT ON P-15
STARTER
STARTER SOLENOID
GROUND

34-18. Typical starter electrical system. This is used on recent model Plymouth cars fitted with Auto-Lite equipment.

On installations where long battery cables would be required, or when more automatic control is desired, a magnetic switch or solenoid, Figs. 34-1 and 34-20, is usually mounted on the starter housing and when current is passed through its windings, heavy contacts are closed which connect the battery to the starter. The magnetic switch is energized by connecting its windings to the starting battery through another switch which is usually mounted on the instrument panel.

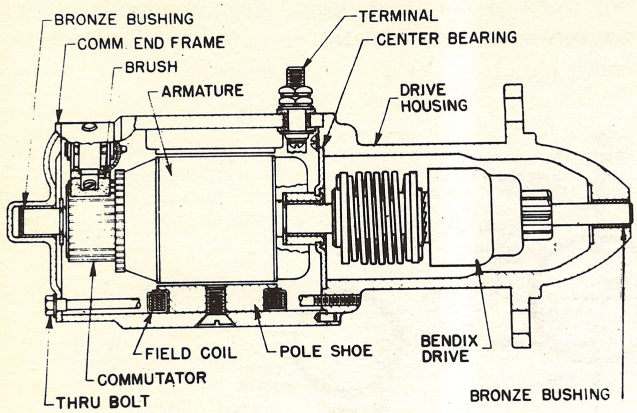

MOTOR SWITCH
COMMUTATOR END FRAME
SHIFT LEVER
BRUSH
DRIVE HOUSING
OILER
COMMUTATOR
THRU BOLT
OVERRUNNING CLUTCH
COVER BAND
ARMATURE
FIELD COIL

34-19. Delco-Remy starting motor fitted with manually operated overrunning clutch.



34-20. Auto-Lite starter fitted with overrunning clutch and solenoid switch.

On starting motors equipped with the Bendix drive, Fig. 34-21, the magnetic switch is usually mounted on the starter and the winding is connected in series with the ignition switch and a push button or engine vacuum operated switch. When the ignition switch is turned on, and the push button operated, the magnetic winding becomes connected to the battery so that the magnetic switches are operated and the circuit between the battery and starter is completed.



34-21. Cranking motor equipped with Bendix drive.

On starters with an overrunning clutch, Fig. 34-20, the solenoid is normally used with a solenoid relay as well as a vacuum switch, Fig. 34-22. Turning on the ignition switch and then depressing the accelerator pedal completes the circuit to the solenoid relay. The relay winding is energized so that the relay contacts close. Closing the relay points connects the solenoid windings directly to the battery so that the solenoid is operated. The solenoid shifts the drive pinion into mesh with the flywheel ring gear, and also closes heavy contacts which complete the circuit from the starting motor to the battery. The vacuum switch operates as previously described to open the solenoid circuit after the engine starts.

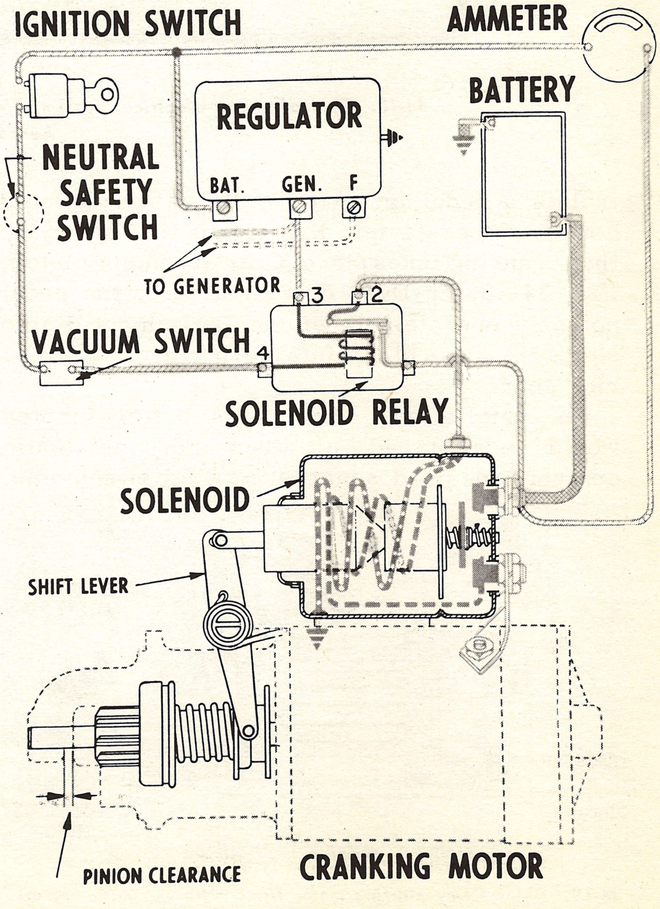
One type of installation, Fig. 34-22, provides added protection against operating the starter while the engine is running, by completing the solenoid relay winding circuit through the generator. When the engine is running, the generator voltage is approximately the same as the battery, so that even though the vacuum switch contacts remain closed, there would be no voltage through the relay winding and the relay would not operate.

The solenoid switch on a starting motor, Figs. 34-20 and 34-23, not only closes the circuit between the battery and the cranking motor, but also shifts the starter pinion into engagement with the flywheel ring gear. This is accomplished by means of linkage between the solenoid plunger, and the shift lever on the starter. When the circuit is completed to the solenoid, current from the battery passes through two separate windings, known as the "pull-in" and "hold-in" windings. The combined magnetic field of these windings pull in the plunger so the drive pinion is shifted into mesh, and the main contacts of the solenoid switch are closed, Fig. 34-24.

Different size wires are used on the two windings, but approximately the same number of turns. The heavy pull-in winding is used to complete the plunger movement, but when the air gap is decreased, the hold-in winding is sufficient to retain the plunger. The closing of the main switch contacts closes the circuit between the battery and the starter and at the same time shorts out the pull-in winding.

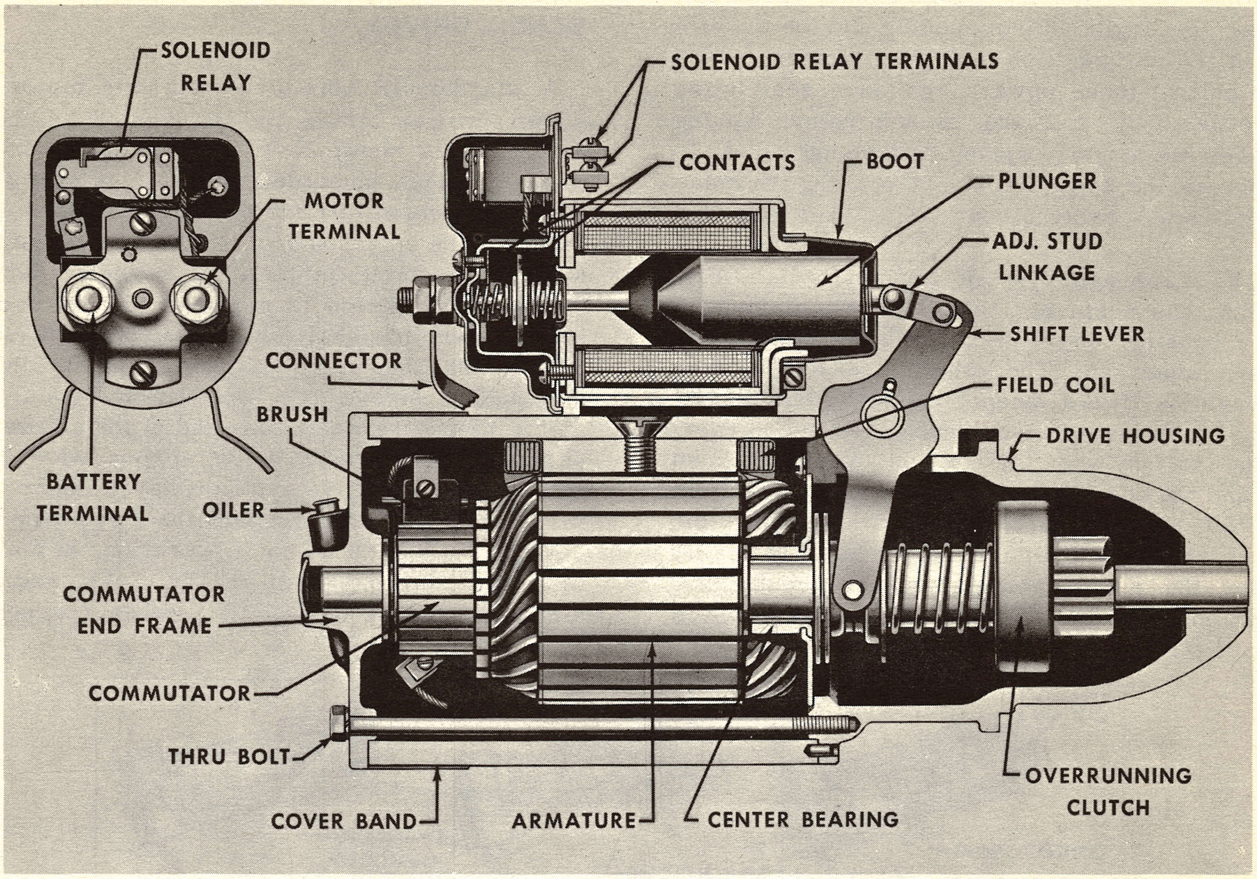
When the control circuit is opened, after the engine is started, current no longer reaches the hold-in winding. However, current flows from the battery through the main switch contacts through the pull-in winding (in reverse direction) and then through the hold-in winding to the ground. With the same number of turns of winding in both coils and the same current, the magnetic forces are equal but opposed and counteract each other. Tension of the return spring then causes the plunger to return to the "at rest" position and break the circuit.

Should cranking continue after the control circuit is broken, it would probably be caused

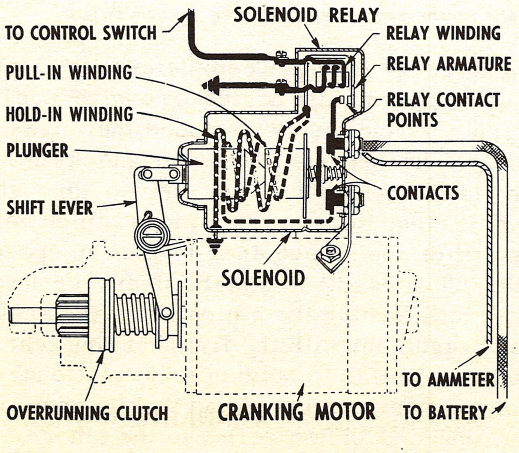


34-22. Starting system using solenoid and vacuum switch.

by shorted turns in the pull-in circuit or a misalignment of the solenoid resulting in binding of the plunger. Low voltage or an open circuit in the hold-in winding will cause an oscillating action of the plunger. Check for a complete circuit of the hold-in winding as well as the condition of the battery whenever chattering of the switch occurs.


SOLENOID RELAY
SOLENOID RELAY TERMINALS
CONTACTS
BOOT
PLUNGER
MOTOR TERMINAL
ADJ. STUD LINKAGE
SHIFT LEVER
CONNECTOR
FIELD COIL
BRUSH
DRIVE HOUSING
BATTERY TERMINAL
OILER
COMMUTATOR END FRAME
COMMUTATOR
THRU BOLT
OVERRUNNING CLUTCH
COVER BAND
ARMATURE
CENTER BEARING

34-23. Delco starting motor with solenoid operated overrunning clutch engagement. At left is end view of solenoid and solenoid relay with cover removed.


SOLENOID RELAY
TO CONTROL SWITCH
RELAY WINDING
PULL-IN WINDING
RELAY ARMATURE
HOLD-IN WINDING
RELAY CONTACT POINTS
PLUNGER
CONTACTS
SHIFT LEVER
SOLENOID
TO AMMETER
OVERRUNNING CLUTCH
CRANKING MOTOR
TO BATTERY

34-24. Wiring circuit of relay and solenoid shown in Fig. 34-23.

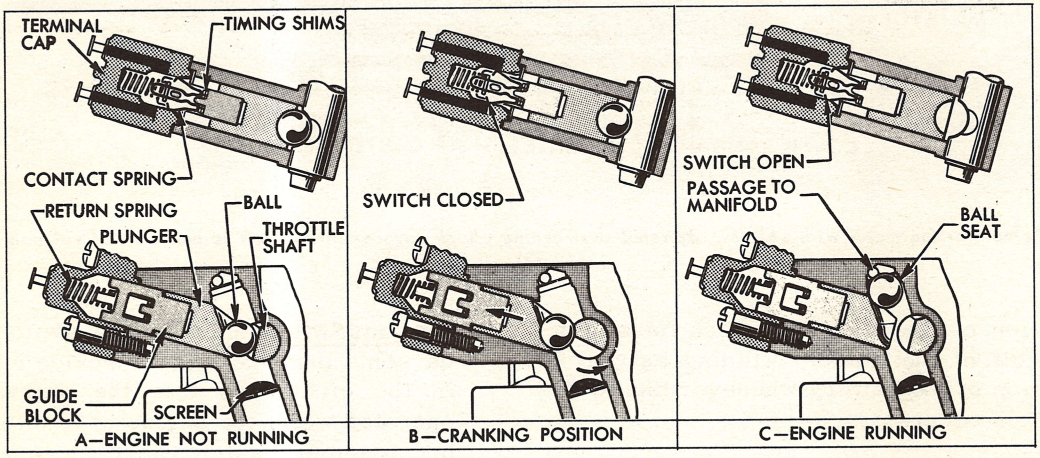
Whenever a solenoid is replaced, it is necessary to adjust the pinion travel. The clearance should be 1/8 to 3/16 in. The exact clearance will vary slightly with different starter designs.

Vacuum Switches: Vacuum switches are used on some installations to provide a safety factor in the circuit so that the starter cannot be operated while the engine is running and also to provide more automatic control of the starting motor. There are two major types of vacuum switches, the diaphragm type and the ball type.

The ball type, Fig. 34-25 and Fig. 34-26, is built into the carburetor and is also known as the carburetor starter switch or the accelerator vacuum switch. The switch consists of a stainless steel ball, plunger, guide block, W-shaped contact spring and return spring housed in a passage in body flange which is closed by a terminal cap containing two contacts.

When the engine is not running and throttle is closed the ball rests on lower end of switch plunger and bears against a flat spot on the throttle shaft and the contacts are not closed. When the accelerator is depressed with the engine stopped and ignition switch turned on, the flat spot on the throttle shaft acts as a cam to push the switch ball and guide block upward until the contact spring closes both contacts in the terminal cap, closing the circuit and putting the cranking system into operation. After the engine starts running and the throttle is in the idle position, manifold vacuum causes the ball to move upward against a seat in the throttle body and the switch return spring pushes the contact spring and plunger down to separate the switch contacts opening the solenoid switch relay circuit, Fig. 34-25, at that point.

The diaphragm type of vacuum switch, Fig. 34-22, has a spring loaded flexible diaphragm in a housing, one side of which is open to the intake manifold. The other side of the diaphragm is linked mechanically to switch contacts. Linkage is also made to the accelerator pedal so that when the ignition switch is turned on and the accelerator is depressed, the vacuum switch contacts are closed to complete the circuit to the starter solenoid relay, Fig. 34-22. After the engine has started and vacuum has developed in the manifold, the vacuum moves the diaphragm in the vacuum switch and locks the switch contacts in the open position. This spots the starting motor and prevents further operation until the engine has stopped.



A—ENGINE NOT RUNNING

B—CRANKING POSITION

C—ENGINE RUNNING

34-25. Ball type vacuum switch. Also known as a carburetor starter switch or accelerator vacuum switch.

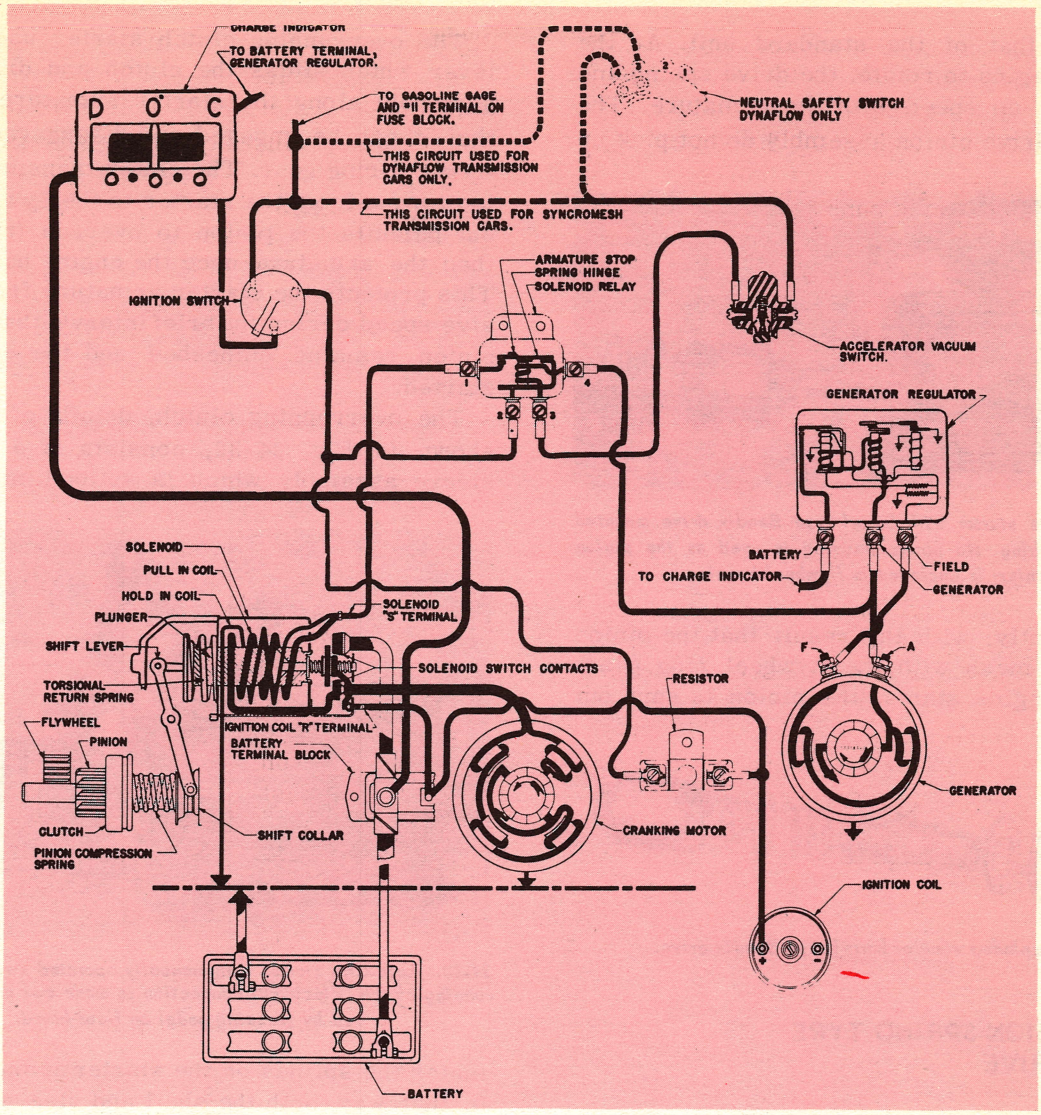
Neutral Safety Switch: All cars equipped with an automatic transmission are provided with a neutral safety switch. The purpose of this switch is to eliminate the possibility of starting the engine while the transmission lever is in a position to drive the car. As shown in Fig. 34-22 and Fig. 34-26, it is connected in series between the accelerator vacuum switch and the ignition switch. On some installations the transmission shift lever may be placed in either "park" or "neutral" position before the circuit to the starter is completed and in other installations, it must be placed in "park" position only.

BENDIX DRIVES

A standard Bendix drive starting motor is shown in Fig. 34-9, and an exploded Bendix drive unit is shown in Fig. 34-27. The Bendix drive provides an automatic means of engaging the drive pinion with the flywheel ring gear for cranking the engine and for automatic disengagement of the starter pinion after the engine starts.

The drive pinion is mounted on a threaded sleeve or hollow shaft which has spiral threads that match the internal threads in the drive pinion. The sleeve is a loose fit on the starter motor armature shaft. One end of the sleeve is bolted to the Bendix drive spring, while the other end of the drive spring is keyed and bolted to the armature shaft through the drive head.

When the starter is not in operation, the pinion is in the position shown in Fig. 34-9, and the pinion is not meshed with the flywheel ring gear. As soon as the circuit is completed to the starter, the starter armature begins to revolve, and being a series wound motor its speed increases very rapidly. The threaded drive sleeve picks up speed with the armature as it is driven through the drive spring. However, the drive pinion being a loose fit on the sleeve does not pick up speed instantly. The result is that the sleeve turns within the pinion, forcing the pinion along the shaft and into engagement with the flywheel ring gear. The action is similar to holding a nut stationary and turning a screw into it so that the nut would move from one end of the screw to the other. As the drive pinion reaches the stop on the end of the

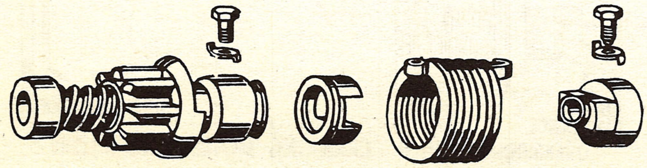

CHARGE INDICATOR
TO BATTERY TERMINAL, GENERATOR REGULATOR.
D O C
TO GASOLINE GAGE AND #11 TERMINAL ON FUSE BLOCK.
THIS CIRCUIT USED FOR DYNAFLOW TRANSMISSION CARS ONLY.
THIS CIRCUIT USED FOR SYNCROMESH TRANSMISSION CARS.
4 3 2 1
NEUTRAL SAFETY SWITCH DYNAFLOW ONLY
IGNITION SWITCH
ARMATURE STOP
SPRING HINGE
SOLENOID RELAY
1
4
2
3
ACCELERATOR VACUUM SWITCH.
GENERATOR REGULATOR
BATTERY
TO CHARGE INDICATOR
FIELD
GENERATOR
SOLENOID
PULL IN COIL
HOLD IN COIL
PLUNGER
SHIFT LEVER
TORSIONAL RETURN SPRING
FLYWHEEL
PINION
CLUTCH
PINION COMPRESSION SPRING
SOLENOID "S" TERMINAL
SOLENOID SWITCH CONTACTS
IGNITION COIL "R" TERMINAL
BATTERY TERMINAL BLOCK
SHIFT COLLAR
CRANKING MOTOR
RESISTOR
F
A
GENERATOR
IGNITION COIL
+
-
BATTERY

34-26. *Cranking system showing location of neutral safety switch, accelerator vacuum switch, ignition coil resistor, etc.*

sleeve, it must then rotate with the sleeve and the armature so that the engine is cranked. The drive spring compresses slightly to absorb the shock of engagement.

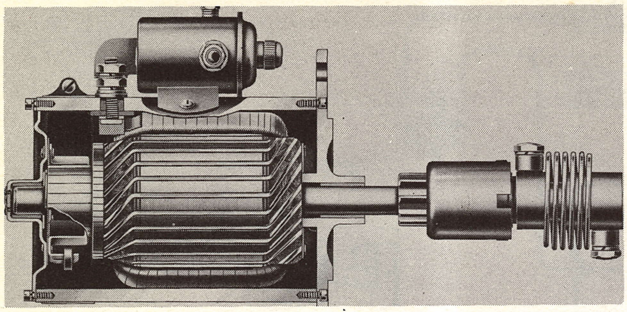
As the engine starts, the flywheel will spin the drive pinion more rapidly than the armature and threaded sleeve are turning, with the result that the pinion is backed out of mesh with the flywheel ring gear.

Some Bendix drive units are provided with a small anti-drift spring between the drive pinion and the pinion stop which prevents the pinion from drifting into mesh when the engine is running. Another design uses a small anti-drift pin and spring inside the pinion which provides sufficient friction to keep the pinion from drifting into mesh.

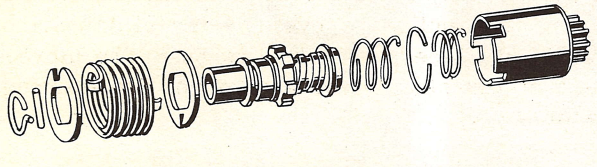


34-27. *Exploded view of standard type Bendix drive.*

Bendix drives are sometimes used with a gear reduction and a barrel type Bendix drive is shown in Fig. 34-28. An exploded view of the barrel type Bendix drive is shown in Fig. 34-29. In this design the drive pinion, as it meshes, moves toward the starting motor and for that reason is referred to as an inboard drive. The barrel which is integral with the drive pinion is assembled on the spiral sleeve of the shaft assembly. The end of the spiral sleeve is attached to the inner end of the drive spring by an anchor plate. The other end of the spring is attached to the armature shaft through the end of the drive shaft assembly. The action of the barrel type Bendix unit is similar to that of the standard unit. As the armature begins to rotate, the drive spring and sleeve pick up speed with the armature. The barrel and drive pinion assembly do not pick up speed instantly, with the result that the pinion moves into mesh with the flywheel ring gear. After the engine starts, the pinion is spun out of mesh.



34-28. Auto-Lite starter with barrel type Bendix drive mounted for inboard meshing. No pinion housing is used as the pinion mechanism is enclosed in flywheel housing.



34-29. Exploded view of barrel type Bendix drive.

COMPRESSION SPRING TYPE BENDIX DRIVE

The operation of a compression spring type inboard Bendix drive is somewhat different from the standard and barrel types. In the compression spring type, meshing of the drive pinion forces the screw sleeve back against the drive spring through the thrust-washer and support so that the drive spring is compressed to absorb the shock of engagement.

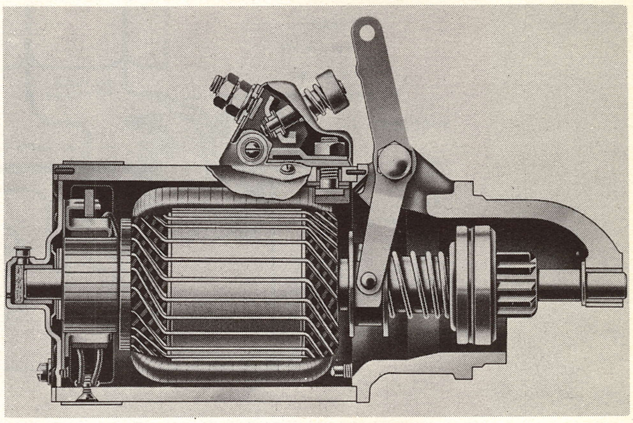
For heavy duty cranking, a friction clutch type Bendix drive is used. This type of drive operates in much the same manner as other Bendix drives, except that it uses a series of spring loaded clutch plates which slip momentarily under shock of engagement.

OVERRUNNING CLUTCH

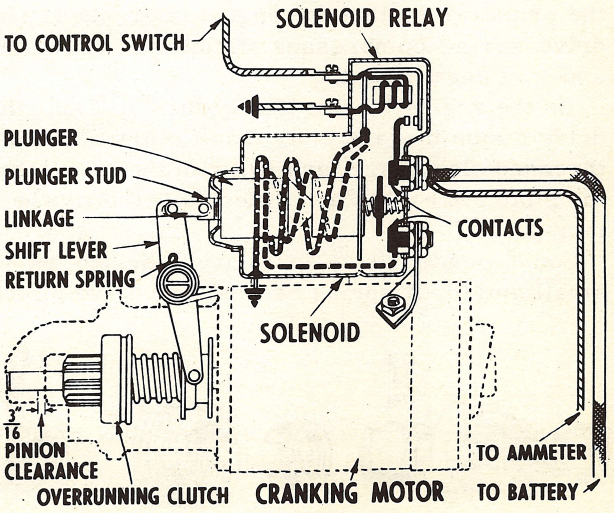
The overrunning clutch is designed to provide positive meshing and demeshing of the starter drive pinion and the flywheel ring gear. A mechanically operated unit is shown in Fig. 34-30, while a solenoid operated unit is illustrated in Figs. 34-23 and 34-31.

The overrunning clutch starter uses a shift lever which slides the clutch and drive pinion assembly along the starter armature shaft so that it can be engaged and disengaged with the flywheel ring gear. The clutch transmits cranking torque from the starter to the flywheel gear, but permits the pinion to overrun (run faster) than the armature once the engine has started. This protects the starter armature from excessive speed during the brief interval that the drive pinion remains enmeshed and the engine has started.

The overrunning clutch, details of which are shown in Fig. 34-32, consists of a shell and sleeve assembly which is splined internally to match the splines on the starter armature shaft. In that way, both the shell and sleeve assembly and armature shaft must turn together. A pinion and collar assembly fits loosely into the shell and the collar is in contact with four hardened still

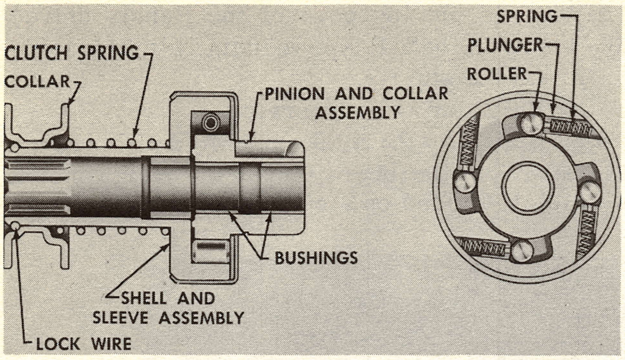


34-30. Auto-Lite starter with manually operated switch and overrunning clutch. Electrical connection is made and clutch is shifted by pressing pedal on floor board.



34-31. Diagram of overrunning clutch, starting motor and solenoid showing pinion clearance and electrical circuit.

rollers which are assembled into notches cut in the inner face of the shell. The notches taper inward slightly so that there is less room in the end away from the rollers than in the end where the rollers are shown in Fig. 34-32. The rollers are spring loaded by small springs and plungers.



*34-32. **Sectional view of overrunning clutch, showing details of construction and location of rollers in clutch.***

When the shift lever is operated, the clutch assembly is moved along the armature shaft until the pinion meshes with the flywheel ring gear. If the teeth should butt instead of mesh, the clutch spring compresses so that the pinion is spring loaded against the ring gear teeth. Then as the armature starts to rotate, the gears are forced into engagement.

As movement of the shift lever is completed, the starter switch, Fig. 34-31, is closed so that the starter armature begins to rotate. This rotates the shell and sleeve assembly causing the rollers to jam tightly in the smaller sections of the shell rotator. The rollers will then jam between the pinion collar and the shell so that the pinion is forced to rotate with the armature and crank the engine.

When the engine starts to operate, it trys to drive the starter armature through the pinion. This causes the pinion to rotate with respect to the shell so that it overruns the shell and armature. The rollers are turned back toward the larger section of the shell notches where they are free and the pinion is therefore permitted to overrun.

This protects the armature for the instant that the car operator leaves his foot on the starter pedal or until the automatic controls take over so that the shift lever is released. The shift lever spring then pulls the overrunning clutch drive pinion out of mesh with the ring gear. The movement of the shift lever also opens the starting motor switch.

QUIZ - CRANKING MOTOR FUNDAMENTALS

1-In which direction does a current carrying conductor tend to move?
  a. From a strong magnetic field to a weak one
  b. From a weak magnetic field to a strong one
2-Describe the reaction of the field of a current carrying conductor with that of the field of a permanent magnet.
3-To what are the ends of an armature coil connected?
4-Describe the operation of a starting motor.
5-In an electric motor, the rotating coils are cutting magnetic lines of force, thereby generating voltage. In which direction does the current flow?
  a. In the same as the applied voltage
  b. Opposed to the applied voltage

6-Why is a series wound motor used for cranking an internal combustion engine?
  a. Higher speed
  b. Higher torque
  c. Constant speed
7-On a light load a series wound motor will rotate at what speed?
  a. Low speed
  b. High speed
  c. Normal speed
8-As the load on a series motor increases, will the current through the armature and fields increase or decrease?
  a. Increase
  b. Decrease
  c. Remain the same
9-What is the purpose of the shunt field coil used together with series coils on some cranking motors?
10-Give four reasons why a starting motor may fail to crank an engine.
11-There are six tests described for use with cranking motors. Name four of them.
12-A burned commutator is usually an indication of what condition?
13-Under load, approximately what current will be flowing through the starting motor?
  a. 50 amp.   c. 200 to 300 amp.
  b. 100 amp.

14-What is the approximate gear reduction between the cranking motor and the engine flywheel?
   a. 1 to 1
   b. 15 to 1
   c. 50 to 1

15-Why is it necessary for the starter pinion to disengage from the flywheel as soon as the engine starts?

16-On what type chassis is a neutral safety switch found and what is its purpose?

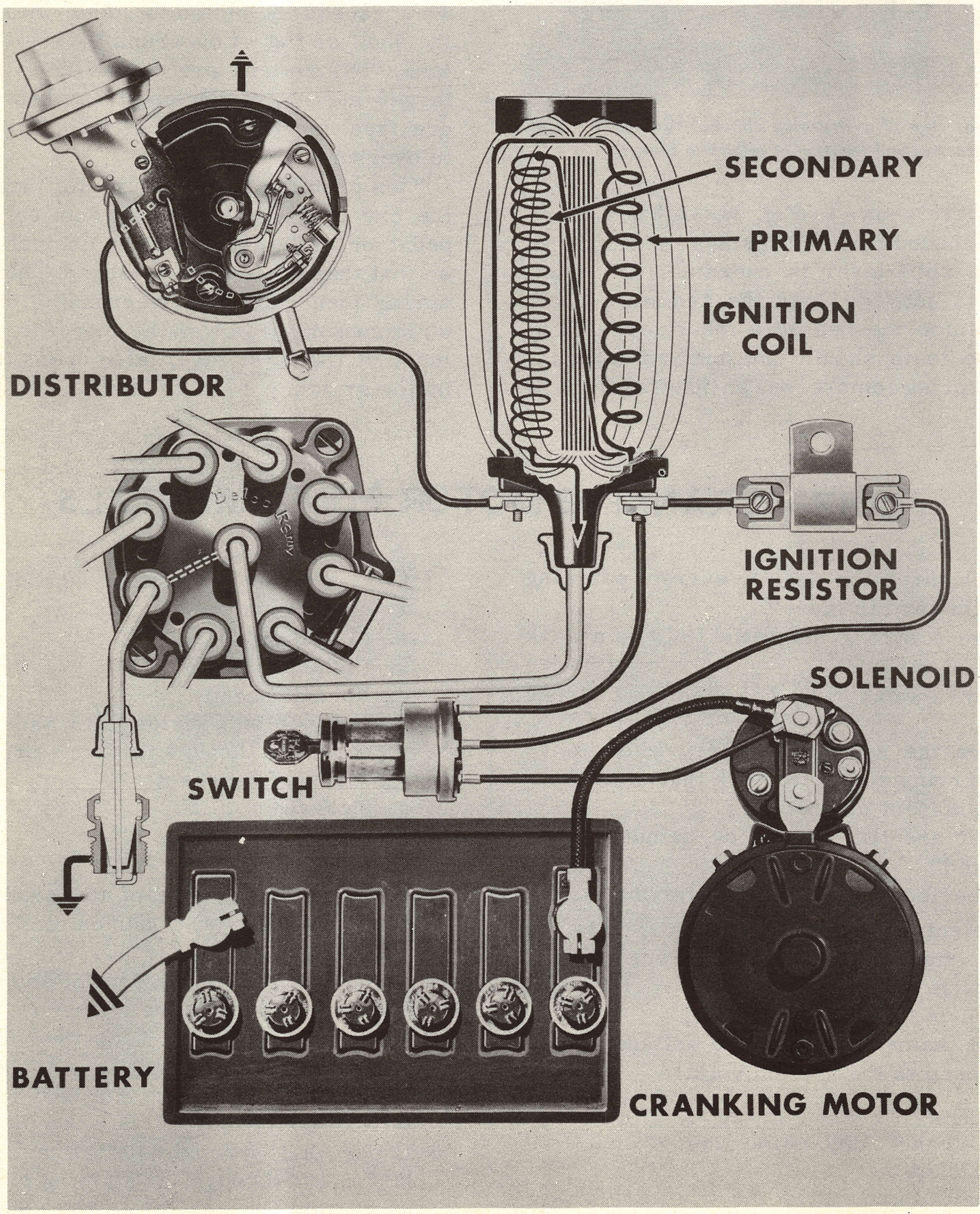
17-What is the purpose of the vacuum switch?
   a. Prevent the starter from being operated while the engine is running
   b. Prevent vacuum in intake manifold from exceeding a certain value
   c. Switch vacuum from one point to another

18-For what purpose is a solenoid used in a starting circuit?

19-What is the purpose of the Bendix drive?

20-Where is the ball type vacuum switch located?
   a. On the starter
   b. Built into the carburetor
   c. Built into the intake manifold

21-Describe the operation of an over running clutch as used on a starter.


SECONDARY
PRIMARY
IGNITION COIL
DISTRIBUTOR
Delco Remy
IGNITION RESISTOR
SOLENOID
SWITCH
BATTERY
CRANKING MOTOR

35-1. *Diagram of ignition circuit.*

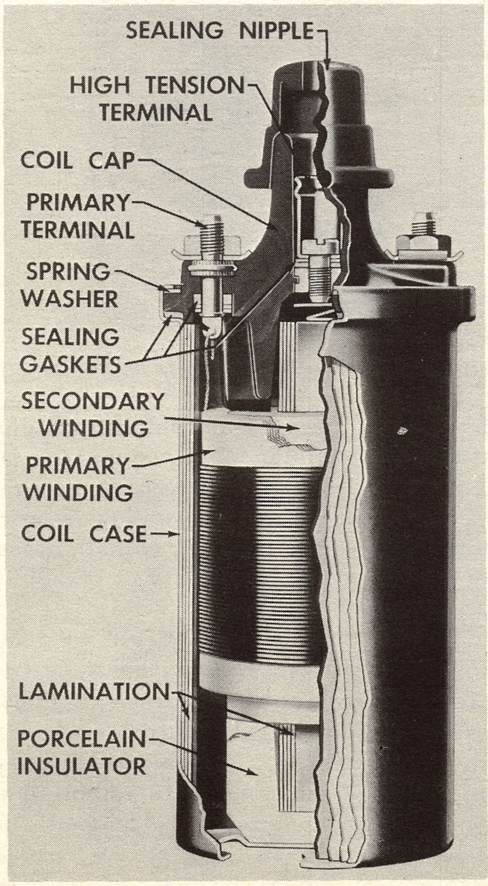
ENGINE IGNITION

BATTERY IGNITION SYSTEMS

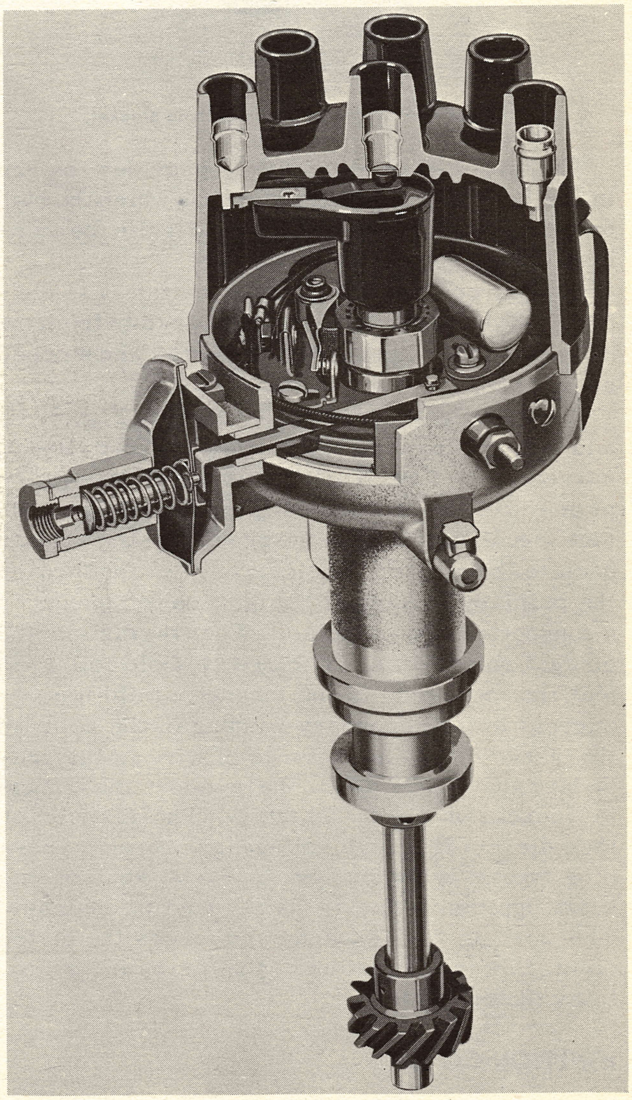
The ignition system on an internal combustion engine provides the spark which ignites the combustible mixture in the combustion chamber.

The modern ignition system, operating from a battery, consists of the battery, ignition coil, distributor, condenser, ignition switch, spark plugs, and the necessary low and high tension wiring. A wiring diagram of a typical ignition system is illustrated in Fig. 35-1.

The purpose of the ignition coil, Fig. 35-2, is transforming or stepping up the 6 or 12 v. from the battery to the high tension voltage of approximately 20,000 v. required to jump the spark plug gap located in the combustion chamber.


SEALING NIPPLE
HIGH TENSION TERMINAL
COIL CAP
PRIMARY TERMINAL
SPRING WASHER
SEALING GASKETS
SECONDARY WINDING
PRIMARY WINDING
COIL CASE
LAMINATION
PORCELAIN INSULATOR

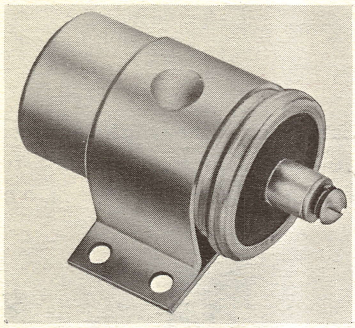
35-2. Sectional view of ignition coil. (AC Spark Plug Division)



35-3. Sectional view of ignition distributor.

The ignition distributor, Fig. 35-3, has several functions. It opens and closes the primary ignition circuit, it distributes the high tension current to the respective cylinders of the engine and also has a mechanism which controls the point at which the breaker points open, thereby advancing or retarding the spark in accordance with engine requirements.

The purpose of the ignition condenser, Fig. 35-4, is to reduce arcing at the breaker points and thereby prolong their life.



35-4. Ignition condenser with mounting bracket.

The spark plug, Fig. 35-5, provides the gap in the combustion chamber across which the high tension electrical spark jumps to ignite the combustible charge.

The purpose of the ignition switch is to connect and disconnect the ignition system from the battery so the engine can be started and stopped as desired.

When the ignition switch is closed, Fig. 35-1, and the ignition distributor contacts also closed, current will flow from the battery, through the primary of the ignition coil, the distributor contact (breaker) points to the ground connection and back to the battery. The current flowing through the primary winding of the ignition coil produces a magnetic field in the coil. When the distributor contact points open, the magnetic field collapses and the movement of the magnetic field induces current in the secondary winding of the coil. As there are many more turns of wire in the secondary than there are in the primary, the voltage is increased up to 20,000 v. The distributor then directs this high voltage to the proper spark plug where it jumps the gap. The heat of this spark ignites the fuel in the combustion chamber. The burning fuel expands and forces the piston down. Downward motion of the piston in turn rotates the crankshaft.

IGNITION COILS

The ignition coil, Figs. 35-2 & 35-6, is a pulse transformer and is designed to step up the low primary voltage as received from the battery and generator of 6 or 12v. to approximately 20,000v. It is composed of a primary and a secondary winding and core of soft iron. The primary winding is made up of approximately 200 turns of relatively heavy wire (approximately No. 18) and the secondary winding may have as many as 22,000 turns of fine wire, (approximately No. 38 gauge). The usual construction is to have the secondary winding wound around the soft iron core and the primary winding surround the secondary. The purpose of the core is to concentrate the magnetic field. This assembly is usually placed in a steel case with a cap of molded insulating materials which carries the terminals. Many coils have their windings immersed in oil. This is done to improve insulation and reduce the effects of moisture. In addition such coils can better withstand corona effects and heat.

When the ignition switch, Fig. 35-1, is closed and the distributor contact points are closed, the current flows through the primary winding of the ignition coil. The current produces a magnetic field around the coil windings. However, this does not occur instantly as it takes time for the current and consequently the magnetic field to reach its maximum value which is determined by either the resistance of the coil winding or the length of time the distributor contacts are closed. In general, the current does not reach the maximum as the contacts remain closed for such a short time, particularly at higher engine speeds.

35-5. Spark plug of the double electrode type.

When the breaker points begin to open, the primary current will tend to continue flowing. This is a natural condition in a winding which is increased by means of the iron core. Without an ignition condenser, the induced voltage causing this flow of current would establish an arc across the contact points and the magnetic energy would be consumed in this arc. As a result the contact points would be burned and normal ignition would be impossible. The condenser prevents this arc by providing a place for the current to flow, thus quickly checking the flow of current. As a result of this action, the magnetic field produced and sustained by the current flow will quickly collapse. It is this rapid collapse of the magnetic field, cutting the windings of the coil, which induces the high voltage in both the primary and secondary windings.

Ignition coils must also be designed to withstand moisture, the heat developed in the windings, and the corona effects. Coils are therefore filled with an insulating material such as oil or paraffin-like material. In addition to providing insulation, the oil or other material must provide rapid heat dissipation and keep corona effects to a minimum. Oil has the advantage that, being a liquid, it automatically heals itself if any breakdown in insulation occurs.

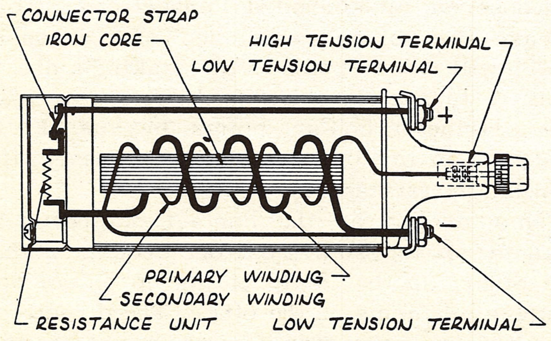
To prevent coils from absorbing moisture, they are hermetically sealed. The outer housing of some makes of coils are finned to increase their cooling.

Heavy duty coils are built with larger cores and also provided with greater insulation. The higher inductance of such coils limits top speed performance to 4,000 engine r.p.m., but their life is materially longer.

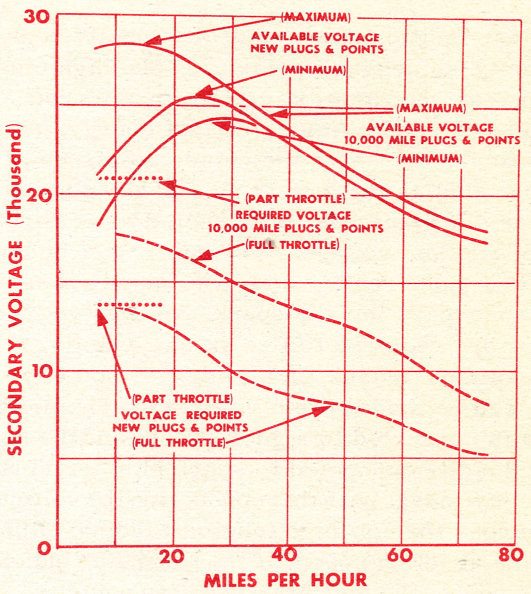
VOLTAGE VARIATIONS AND REQUIREMENTS

Engine speed, compression pressures, carburetor mixture ratios, spark plug temperatures, width and shape of plug gap will all affect the voltage required to produce a spark at the plug gap.

As previously pointed out, the length of time the ignition points are closed (which in turn is dependent on engine speed) will affect the voltage produced by the coil. However, there is a wide range between maximum and minimum voltages produced at low engine speeds, Fig. 35-7. This range in voltage is caused by increased tendency toward arcing under such conditions. Whenever an arc occurs at the breaker points, the voltage induced in the secondary winding is reduced. Obviously when such voltage reaches the minimum required to jump the gap at the plug, missing will occur.



35-6. *Details of ignition coil, showing the primary and secondary windings and terminals.*



35-7. *Variation of ignition voltage under different conditions.*

New distributor contact points, correctly installed, make possible the maximum voltage from the coil secondary. New plugs have the lowest firing requirements and after use the electrodes of the plugs become worn and eroded and a higher voltage is required to jump the gap. After approximately 10,000 miles of operation, the points will also be covered with oxide which will lower the minimum voltage available at low speeds. In addition plug gaps often increase as much as .015 in. (approximately 50 per cent).

It is therefore necessary that a margin of voltage be available over and above that required to fire a plug under ideal conditions. Install the coil as close to the distributor as possible to greatly aid ignition conditions. In addition the distributor should be centrally located in respect to the engine so that spark plug leads will be as short as possible. Coil terminals must be connected correctly so as to insure negative polarity at the high tension terminal.

Keeping all high tension leads as short as possible reduces the electrostatic capacity of the system and thereby increases the voltage available at the plugs.

A higher voltage is also required when carburetor mixtures are lean. Such voltage may be as much as 40 per cent higher than normal requirements. The highest voltage requirements exist at low engine speed under very light acceleration. Missing under such conditions is a direct indication that there is insufficient voltage available to fire the plug.

NEGATIVE HIGH TENSION POLARITY

Most ignition manufacturers specify negative polarity as negative polarity of the high tension outlet of the ignition coil is considered as a means of conserving electrical energy. This is due to the fact that the center electrode of the spark plug is the hottest part of the plug. When the center electrode is connected to the negative high tension voltage, the spark gap becomes ionized more readily and thus forms a lower resistance path for the spark. A lower voltage is therefore required to fire the same plug gap.

A simple means of testing coil polarity on a car can be made with a voltmeter. The positive lead is connected to a good ground and the negative lead is connected to spark plug terminal of No. 1 cylinder. With this connection the voltmeter is across the coil high tension windings. Run the engine at idling speed. If the voltmeter indicates "up" scale, the coil has a negative polarity.

An ordinary lead pencil can be used to check polarity. Insert the pencil point in the gap between the end of the ignition cable and the spark plug terminal. If the flare appears on the plug side, the polarity is correct.

IGNITION CONDENSERS

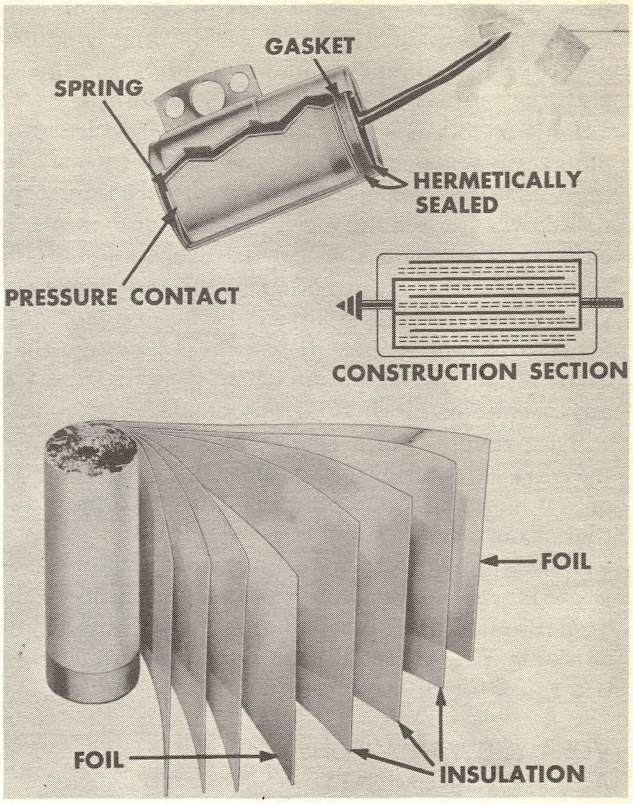
Ignition condensers are provided to prevent an arc at the distributor contact points when the points first open. This is accomplished by providing a place where current can flow until the contact points are fully open.

Condensers are made of alternate sheets of metal foil and insulation. The sheets of foil are of slightly smaller area than the insulating sheets and, as shown in Fig. 35-8, alternate sheets of foil are connected to one terminal of the condenser, while the remaining sheets of foil are connected together to provide the other terminal. The condenser is connected directly across the distributor contact points.

Condenser action requires a high quality insulation between the sheets of foil and in automotive condensers, the sheets of foil and insulation are in the form of long narrow strips which are then rolled to form a compact cylinder.

In order to eliminate the possibility of moisture entering the condenser, they are hermetically sealed.

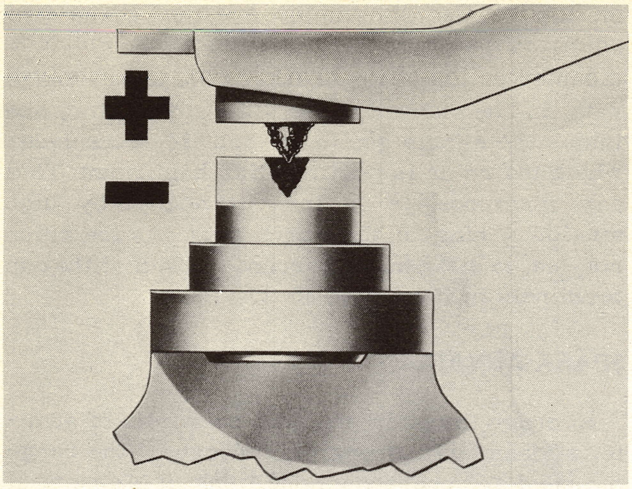
The capacity of a condenser is measured in microfarads and is proportional to the total area of the foil and inversely proportional to the thickness of the insulating sheets which are called the dielectric. In other words, the thinner the dielectric the greater the capacity of condenser. Ignition condensers usually vary in capacity from .15 to .25 microfarad.



35-8. Construction details of Delco-Remy ignition condenser.

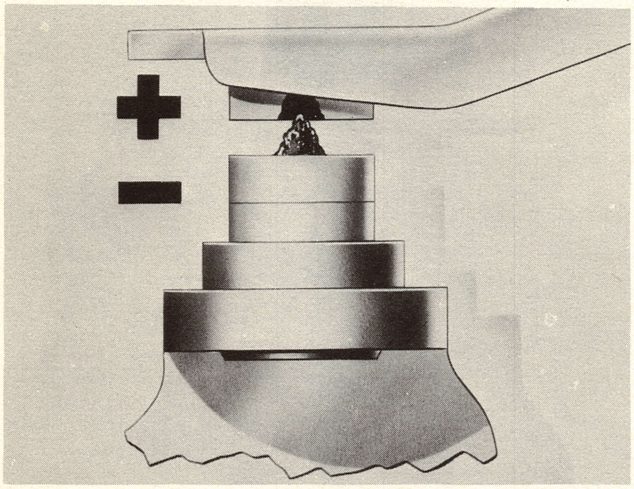
Loosened or corroded connections will increase the series resistance of a condenser which will cause it to be slow in taking a charge. This in turn causes high voltage and arcing at the distributor contact points. In general a resistance up to .5 ohm does not seriously affect ignition performance.

This arcing at the contact points causes transfer of tungsten from one breaker point to the other, so that a tip builds up on one point while a pit forms on the other. The direction in which the tungsten transfers can be used as basis for trouble shooting and correction of the pitting. If the material transfers from the negative to the positive point, Fig. 35-9, one or more of these corrections can be made: Increase condenser capacity, shorten condenser lead, separate distributor-to-coil low and high tension leads, move these leads closer to ground.



35-9. *Low condenser capacity causes transfer of metal from negative to positive breaker point.*

If the tungsten transfers from the positive to the negative point, Fig. 35-10, reduce condenser capacity, move distributor-to-coil leads closer together, move these leads away from ground or lengthen condenser lead.



35-10. *High condenser capacity uses transfer of metal from positive to negative breaker point.*

VIBRATOR TYPE IGNITION COIL

The vibrator type of ignition coil, Fig. 35-11, consists of the conventional primary and secondary windings and soft iron core. In addition, it is provided with a set of contact points which are connected in series with the primary winding and are mounted so that the magnetic field from the core will pull the movable or vibrating point away from the stationary point and, in that way, the primary circuit is opened and closed.

Vibrating type ignition coils were used for many years in the early days of the industry and popularly known as the Model-T coil. Today they are used primarily for starting Diesel engines.

These coils are constructed with the primary next to the core and the secondary on top of the primary. As a result, it is necessary to make the coil case of insulating material.

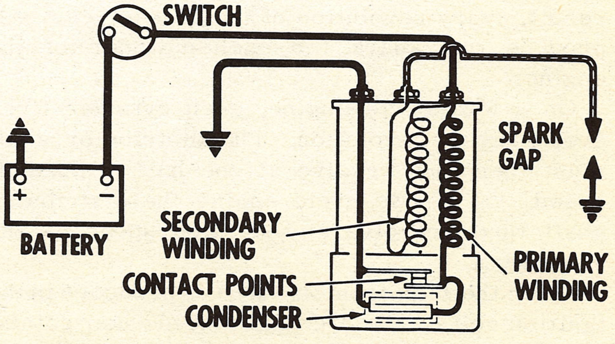
In operation, current flows through the primary winding and creates a magnetic field, which attracts the armature carrying one of the sets of contact points. This causes the contact points to separate and open the primary circuit. This in turn causes the magnetic field to collapse, releasing the armature so that the points close, re-establishing the flow of current through the primary winding. This cycle is repeated at a rate dependent on the stiffness of the armature spring. Each time the magnetic field is built up and collapses, current is induced in the secondary winding and a stream of sparks will jump between the secondary leads when they are held close together. A condenser is connected across the vibrator contacts to prevent an arc from forming and bringing the current flow to an abrupt stop.

On the Model-T Ford and other engines using the vibrator type coil, a secondary lead was connected to a spark plug and the other lead grounded. One coil was provided for each cylinder and the distributor handled primary current only.

On Diesel engines the stream of sparks is used to ignite a spray of oil in the intake manifold, in order to obtain easier starting under low temperature conditions.

IGNITION DISTRIBUTORS

The ignition distributor is designed to make and break the primary ignition circuit, and also to distribute the high tension current to the proper spark plug at the correct time. It is driven at one half crankshaft speed on four cycle engines, and is usually driven by the camshaft, though in



35-11. *Circuit of vibrator type ignition coil.*

some cases an accessory shaft is used. In order to keep high tension leads as short as possible, it is desirable to have the distributor centrally located in respect to the engine. However, in many designs the distributor is mounted at the front or rear of the engine.

Detailed construction of the ignition distributor varies considerably with different manufacturers. Basically, it consists of a housing into which the distributor shaft and centrifugal weight base assembly are fitted with suitable bearings. In most cases, these bearings are of the bronze bushing type, though heavy duty distributors frequently employ ball bearings. In low-priced distributors, the shaft will turn directly in the cast iron housing of the distributor.

Details of a recent model Delco distributor are shown in Fig. 35-12. A window in cap is provided for easy adjustment of the breaker point gap, while cap is in position. The circuit breaker plate located below the centrifugal advance mechanism uses the outer diameter of the main shaft bushing for its bearing surface. A retainer clip in the upper shaft bushing holds the movable plate in position. The contact set is attached to the movable breaker plate. A vacuum advance control unit, attached to the distributor housing is mounted under the movable breaker plate. The rotor serves as a cover for the centrifugal advance mechanism which consists of an automatic cam actuated by two centrifugal weights.

As the breaker cam is rotated, each cam lobe passes under the breaker lever rubbing block. This causes the breaker points to separate. As these are connected in series with the primary winding of the ignition coil, current will pass through that circuit when the points are closed. When the points open, the magnetic field collapses and a high tension voltage is induced in the secondary winding of the ignition coil.

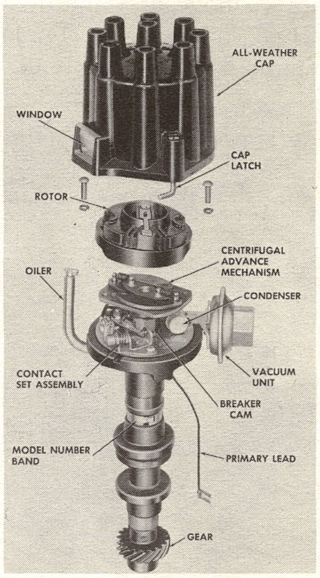
The usual design is to provide one lobe on the breaker cam for each cylinder of the engine. A six-cylinder engine will therefore have a six-lobe cam in the distributor, and an eight-cylinder will have an eight-lobe cam, Fig. 35-12. As a result, every revolution of the breaker cam will produce one spark for each cylinder of the engine.

On a four-cycle engine, each cylinder fires every other revolution. The distributor shaft must therefore revolve at one half crankshaft speed. On a two-cycle engine the distributor shaft would revolve at the same speed as the crankshaft.

After the high tension surge is produced in the ignition coil by the opening of the breaker points, the current passes from the coil to the center terminal of the distributor cap which is mounted on top of the distributor housing. From that point, it passes down to the rotor which is mounted on top of the breaker cam and revolves with it. The current passes along the rotor, and jumps the minute gap to the cap electrode under which the rotor is positioned at that instant. This cap electrode is in turn connected by high tension wiring to the spark plug. As the rotor rotates, it distributes current to each of the cap terminals in turn, Fig. 35-1.

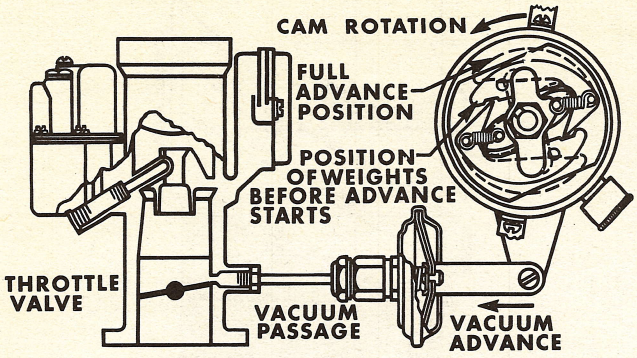
SPARK ADVANCE

In order to obtain efficient operation of an internal combustion engine, throughout the range of speed and operating conditions, it is essential that the spark occur at the correct instant. That instant will vary according to engine load and speed. Mechanism is, therefore, provided to automatically advance and retard the spark as conditions require. On automotive engines two methods are usually provided: these are by centrifugal force and engine vacuum.



35-12. Details of typical Delco-Remy distributor.

When the engine is idling the spark is usually timed to occur just before the piston reaches the top of the compression stroke. Under idling conditions or, when driving at a sustained speed under part throttle conditions, cylinders take in only part of the full charge. As a result, compression pressures are relatively low, and as a consequence combustion is slow and must be started earlier. At higher engine speeds, there is a shorter interval of time for the mixture to ignite and expand. Therefore, in order to obtain the maximum amount of power at higher speeds, it is necessary to have the spark occur slightly earlier in the engine cycle. This is accomplished by means of the centrifugal advance mechanism, Figs. 35-12 and 35-13. In Fig. 35-12 the advance mechanism is above the contact set assembly, and in Fig. 35-13 it is below the ignition breaker plate. The mechanism consists of two weights, which the centrifugal force developed by the rotating shaft tends to throw outward against the tension of springs. The faster the distributor shaft rotates, the greater the centrifugal force, and the greater the movement of the advance weights. The movement of the weights is transmitted to the breaker cam so that the cam is rotated to an advanced position in respect to the distributor drive shaft. In other designs, the cam is integral with the distributor shaft, and the movement of the centrifugal weights will rotate the breaker plate around the axis of the distributor shaft.

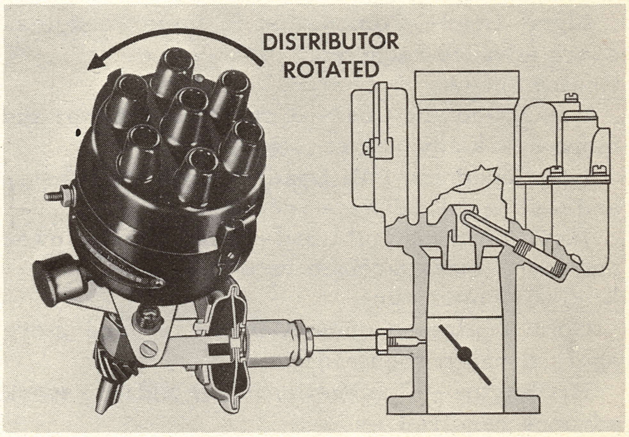


35-13. Diagram showing details of centrifugal and vacuum advance mechanism. (Delco-Remy)

The amount of centrifugal advance required varies considerably for each make and model of engine and is determined experimentally on a dynamometer. Under part throttle operation, the intake manifold is high and, therefore, a smaller amount of mixture is sucked into the engine and compression pressure is low. With lower pressures, the mixture does not burn as rapidly, and to obtain maximum efficiency under such conditions, the spark should be advanced more than that obtained by the centrifugal mechanism. This additional advance is obtained by means of the vacuum advance mechanism.

VACUUM ADVANCE

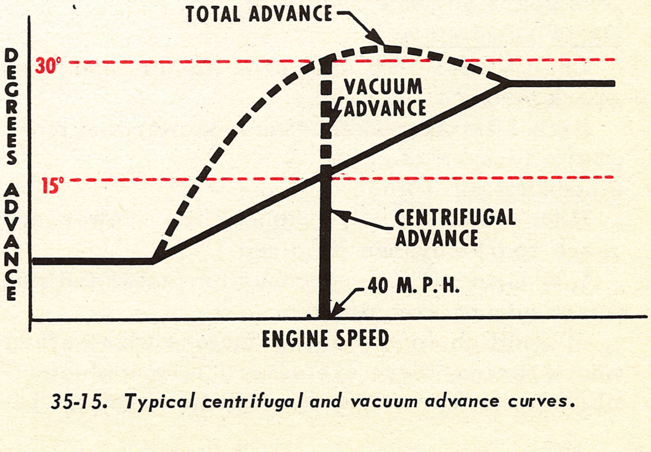
The conventional vacuum advance mechanism, Fig. 35-13, utilizes the vacuum in the intake manifold to provide the additional spark advance required under part throttle operation and has a spring loaded diaphragm connected by linkage to the ignition distributor. The spring loaded side of the diaphragm is airtight and is connected by tubing to a point on the atmospheric side of the carburetor throttle, when the throttle is in the idling position. With the throttle in the idling position, there is virtually zero vacuum at the point where the vacuum spark control connection is made. However, as soon as the throttle is opened, it swings past the opening of the vacuum passage and the vacuum can then act on the diaphragm of the spark advance mechanism. This causes the diaphragm to deflect and its motion is transmitted by linkage to the distributor. In some designs, the distributor is rotated on its mounting, Fig. 35-14, while in other designs the breaker plate is rotated.



35-14. Vacuum advance mechanism on a Delco-Remy distributor which rotates the distributor in its mounting.

The amount of movement is of course proportional to the amount of vacuum. At any particular engine speed there will be a definite amount of spark advance resulting from the operation of the centrifugal advance mechanism, plus an additional amount of advance resulting from the vacuum advance mechanism.

For example, Fig. 35-15 shows that the centrifugal advance at 40 m.p.h. supplies 15



35-15. Typical centrifugal and vacuum advance curves.

deg. spark advance. If the throttle is only partly opened, an additional vacuum advance of up to 15 deg. may be obtained. However, if the throttle is opened completely, the manifold vacuum will approach zero with the result that there will be no spark advance provided by the vacuum spark advance mechanism. Another curve or chart of spark advance showing the rapid decrease in vacuum advance between 20 per cent engine load and full load is shown in Fig. 35-16.

FACTORS GOVERNING SPARK ADVANCE

Engine Load:

Less Load---Combustion is slower and more spark advance required.

More Load---Combustion is faster and less spark advance required.

Engine Speed:

Low Speed and Load---Combustion slower and more spark advance required.

Low Speed and Full Load---Combustion faster and less spark advance required.

High Speed and Full Load---Combustion slower and more spark advance required.

Engine Temperature:

Cold Engine---Combustion slower and more spark advance required.

Hot Engine---Combustion faster and less spark advance required.

Cylinder Bore:

Larger Bore---Combustion slower and more spark advance required.

Smaller Bore---Combustion faster and less spark advance required.

Compression Ratio:

Low Compression Ratio---Combustion slower and more spark advance required.

High Compression Ratio---Combustion faster and less spark advance required.

Character of Fuel:

Low Volatile Fuel---Combustion slower and more spark advance required.

High Volatile Fuel---Combustion faster and less spark advance required.

Air-Fuel Mixture:

Lean Mixture---Combustion faster and less spark advance required.

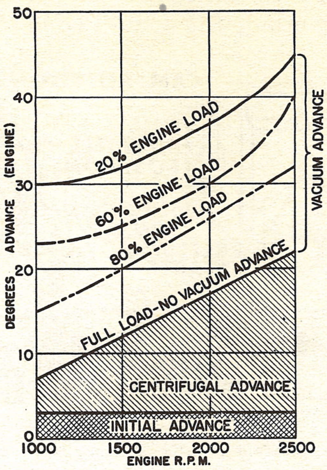
Rich Mixture---Combustion slower and more spark advance required.

Knock Rating of Fuel:

High Octane Fuel---Combustion slower and more spark advance required.

Low Octane Fuel---Combustion faster and less spark advance required.

In addition to the above factors which affect spark timing, there are several others which include the shape of the combustion chamber, location of the spark plug, carbon accumulation in the combustion chamber, equality of fuel and distribution to the individual cylinders.



35-16. A chart of the engine spark advance on a typical V-8, high compression engine, showing the rapid decrease in vacuum advance between 20 per cent engine load and full engine load. Spark advance requirements will vary with different engines.

CAM ANGLE

Cam angle or dwell angle is the number of degrees through which the distributor cam rotates, while the ignition points are closed. It is directly related to the breaker point gap. Decreasing the breaker point gap will increase the cam angle. In a six-cylinder engine the average cam angle is 36 deg. As there are 60 deg. of cam rotation devoted to firing each cylinder of a six-cylinder engine the points are open for 24 deg. and closed for 36 deg. The cam angle of an eight-cylinder engine is approximately 31 deg., while on a four-cylinder engine the cam angle would be about 41 deg.

The breaker point gap or cam angle must be set very accurately. If the cam angle is too small, there will be insufficient time for the current to pass through the primary winding of the ignition coil, and a weak spark will result. If the cam angle is too great, the breaker points will not open far enough so that they will tend to stick together, and misfiring will result. The best method of adjusting the breaker points, is by means of a dwell meter, though many mechanics will use a thickness gauge.

FORD LOADOMATIC ADVANCE

Spark advance on the Ford Loadomatic distributor, Fig. 35-17, is controlled entirely by vacuum. The demands of the engine are satisfied by the action of the breaker plate, which is controlled by a vacuum actuated diaphragm working against the action of two calibrated breaker plate springs. The breaker plate is free to rotate on the shaft upper bushing. The diaphragm moves the breaker plate in a counterclockwise direction to advance the spark, and the springs move the plate in a clockwise direction, to retard the spark. The degree of spark advance is determined by the strength of the vacuum acting on the diaphragm.

Vacuum is transmitted to the distributor diaphragm from three interconnected passages in the carburetor, Fig. 35-17. Older designs used only two passages in the carburetor and did not have a spark valve. The opening of one passage is in the throat of the venturi, and the openings of the other two passages are in the throttle bore, just above the closed throttle plate.

All manifold vacuum passes through a spark control valve located in the carburetor throttle body, Fig. 35-17. Under steady part open throttle operation, the spark valve is held open against the pressure of a calibrated spring. A combination of atmospheric pressure outside of the spark valve diaphragm, and manifold vacuum from within, holds the spark valve open. When accelerating, manifold vacuum momentarily drops below a predetermined point, and the calibrated spring closes the spark valve shutting off the manifold vacuum to the distributor, which prevents excessive spark advance. Vacuum from the venturi prevents full spark retard. As engine speed approaches the throttle setting, manifold vacuum increases sufficiently to open the spark valve, and allow a higher vacuum to operate the diaphragm in the distributor.

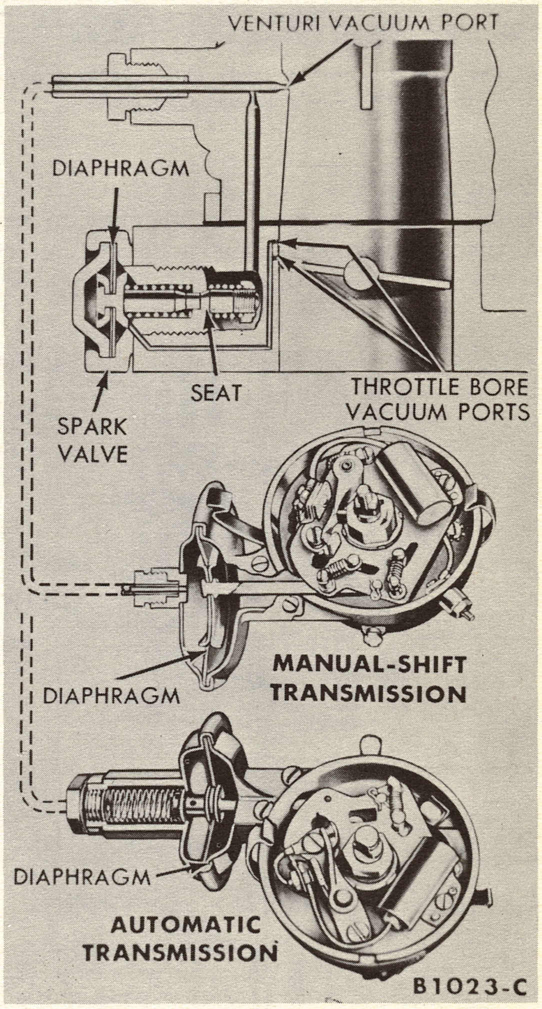
At high engine speed, manifold vacuum falls and the valve closes. This prevents loss of venturi vacuum due to bleed back caused by lower manifold vacuum. This assures full spark advance at high engine speeds.

The spark valve operates in a similar manner to provide an intermediate spark retard, whenever the load on the engine is increased to a degree where normal road load spark advance would be too great, and the wide open throttle retard would reduce the efficiency of the engine.

On Ford cars using the Loadomatic distributor and automatic transmission, the operation is somewhat different. Vacuum to the distributor is transmitted in the same manner to the distributor, as is used with the manual shift transmission. However, the distributor used with the automatic transmission has three spark advance systems, Fig. 35-17. At part throttle operation, there is a rapid spark advance which is controlled by the breaker plate spring. A stop in the vacuum chamber allows steady advance at steady part throttle operation. Additional advance at higher speeds, is controlled by calibration shims, located between the spring and vacuum connection in the diaphragm housing.

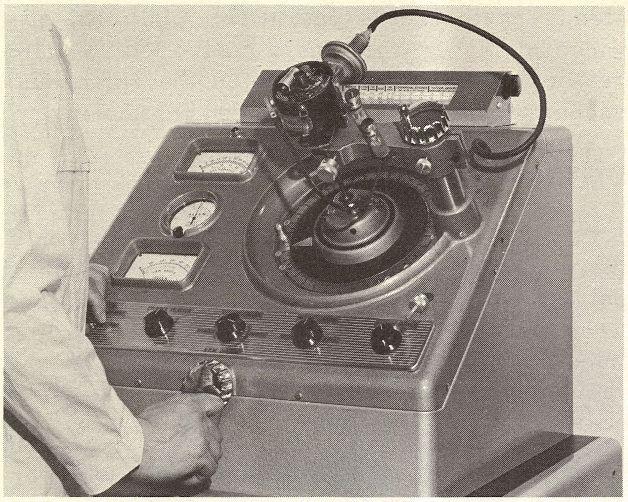
DISTRIBUTOR SERVICE

Complete distributor service includes not only the replacement of the distributor breaker points, but also the testing and replacement, when necessary of the condenser, rotor, distributor cap, distributor cam, centrifugal and vacuum advance mechanism and distributor shaft bearings.

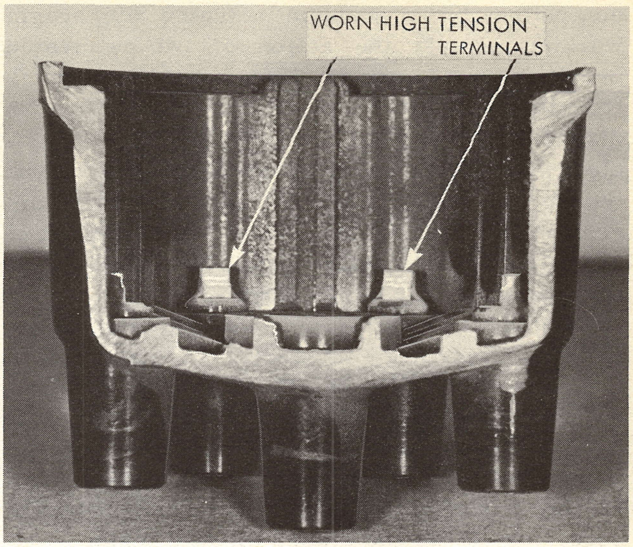


35-17. Ford Loadomatic distributor as used on cars with manual shift transmission and with automatic transmission.

To properly test a distributor to make sure all parts are functioning correctly, distributor testing equipment as shown in Fig. 35-18 is required. Such equipment will check the spacing or dwell of the ignition points, the degree of advance at various speeds, wear of the distributor cam as indicated by the regularity and spacing of the sparks.



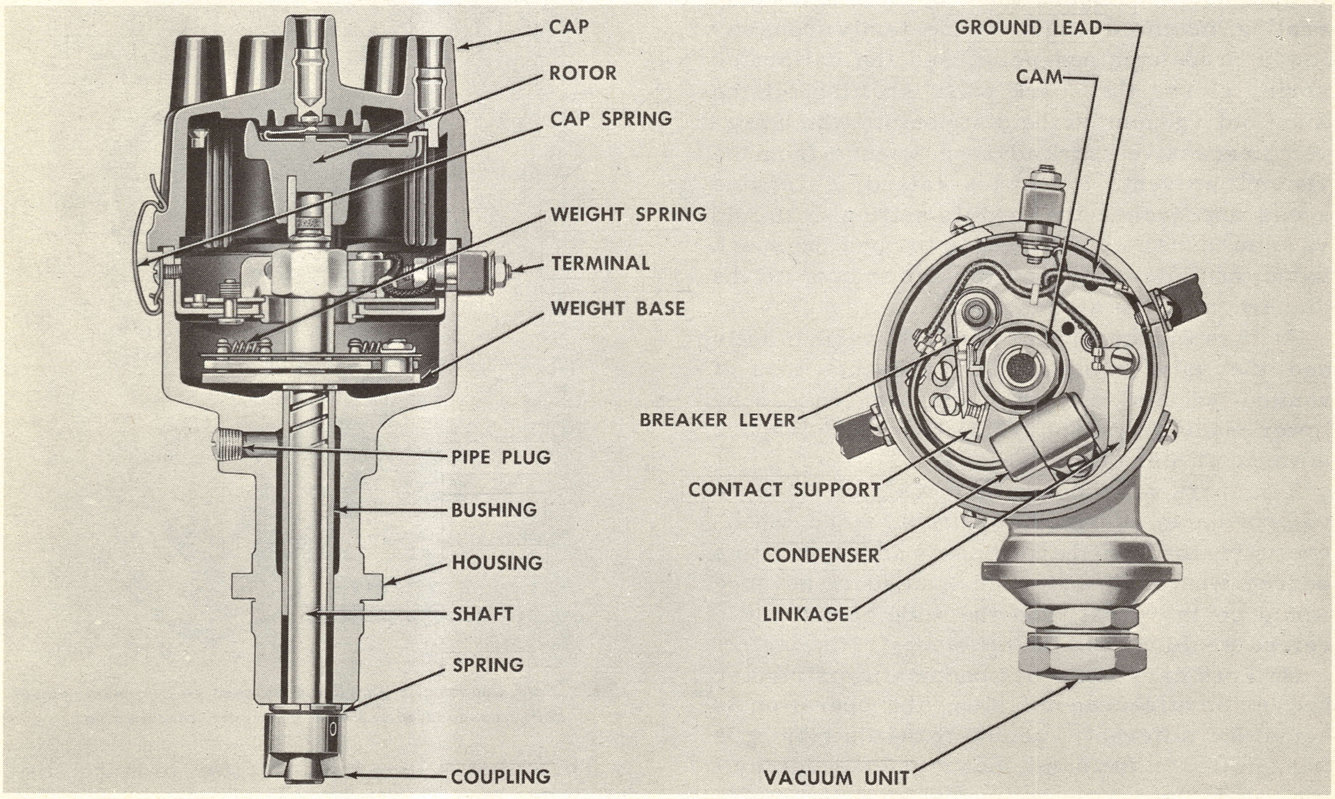
35-18. *One type of distributor tester which checks cam angle, degree of spark advance and spark pattern.*


WORN HIGH TENSION TERMINALS

35-19. *Part of distributor cap cut away to show eroded condition of firing points.*

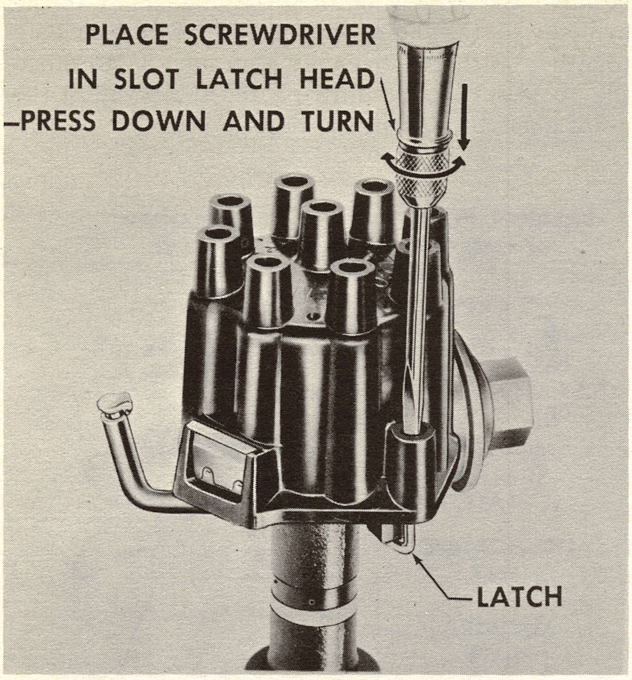
Distributor Caps:

These should be carefully checked to make sure that sparks have not been arcing from point to point within the cap. Neither should there be any cracks in the cap, and both interior and exterior must be clean and free from dirt. The firing points should not be eroded, Fig. 35-19, and the interior of the towers must be clean and free from corrosion. If necessary, the interior of the towers can be cleaned by means of a round wire bristle brush. When cleaning distributor caps, care must be exercised not to use any cleaning solution that would injure cap which is usually made of some form of Phenol-resin.


CAP
ROTOR
CAP SPRING
WEIGHT SPRING
TERMINAL
WEIGHT BASE
PIPE PLUG
BUSHING
HOUSING
SHAFT
SPRING
COUPLING
GROUND LEAD
CAM
BREAKER LEVER
CONTACT SUPPORT
CONDENSER
LINKAGE
VACUUM UNIT

35-20. *Illustrating parts of a distributor. (Delco)*

There are two principal methods of holding the distributor cap in place on the distributor housing. One is by means of external clips or cap springs, Fig. 35-20, and the other is by means of a latch as shown in Fig. 35-21. The former is easily removed by pulling back the clips, permitting the lifting off of the cap from the distributor housing. In the case of the latch, the cap is removed by inserting a screw driver in upper slotted end of cap retainer, press down and turn until the latch is disengaged.



35-21. *Method of removing distributor cap from one type of Delco-Remy distributor.*

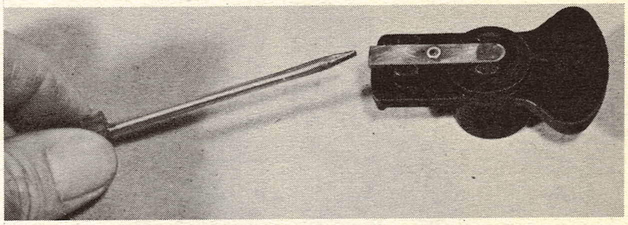
Rotors:

Rotors are designed to distribute the high tension current to the towers of the distributor cap. They are provided with some sort of spring connection to the center tower or terminal and this spring must have ample tension to provide good electrical contact. The firing end of the rotor, Fig. 35-22, from which the high tension spark jumps to each of the terminals in turn should not be worn in any way, as any wear or irregularity will result in excessive resistance to the high tension spark. Most rotors are designed simply to carry the high tension current. However, some are designed to include a resistor for the suppression of radio and TV interference.

Rotors are mounted on the upper end of the distributor shaft, Fig. 35-20, and in most cases all that is necessary to remove them is to pull them off. In that connection the rotor must have a snug fit on the end of the shaft. On another design, two screws are used to attach the rotor, Fig. 35-23, to a plate on the top of the distributor shaft.

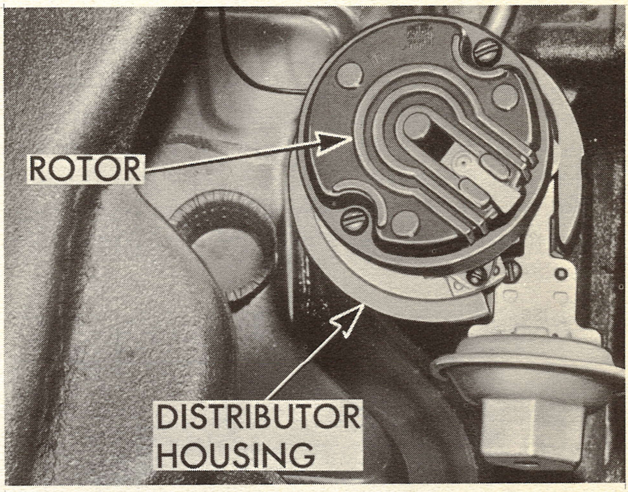
Distributor Shaft:

There should not be more than .002 in. side clearance between the shaft and its bearings. The gear and its coupling or drive must be tight on the end of the shaft, and not be worn.



35-22. *Firing end of rotor must not be worn.*

When replacing bushings in the distributor housing, these should be removed by a special puller or press, Fig. 35-24, and most manufacturers recommend that the bushings be burnished after installation, Fig. 35-25. However, the porous bushings used in many Delco-Remy units are manufactured to exact size and should not be reamed, scraped or filed. Some bushings should be soaked in engine oil prior to installation.



35-23. *This type rotor is attached to top of distributor shaft by means of two screws.*

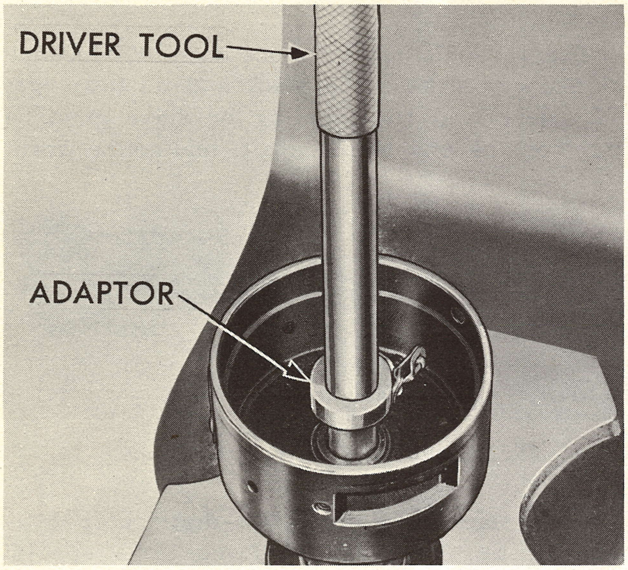
Breaker Plate:

The bearings of the breaker plate must not be worn and must operate smoothly. In the case of the Delco-Remy center bearing breaker plate, Fig. 35-26, by means of a spring balance, the spring tension can be measured, Fig. 35-27.

Breaker Cam:

The breaker cam must be smooth and not worn.

Any inaccuracies will be disclosed when the assembled distributor is tested on the distributor tester, Fig. 35-18, by an examination of the spark pattern. On assembly the cam should be given a very light coating of special grease.



35-24. Pressing out bushings from distributor housing.

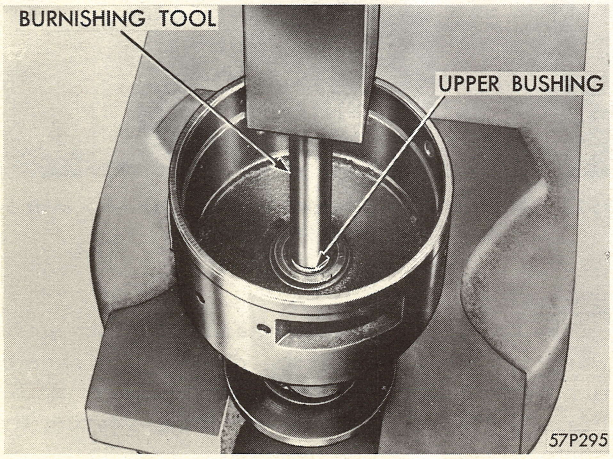
Insulators:

The insulators at the primary lead connection, Fig. 35-30 should be checked to make sure they are in good condition, and there is no possibility of any grounds.

Breaker Points:

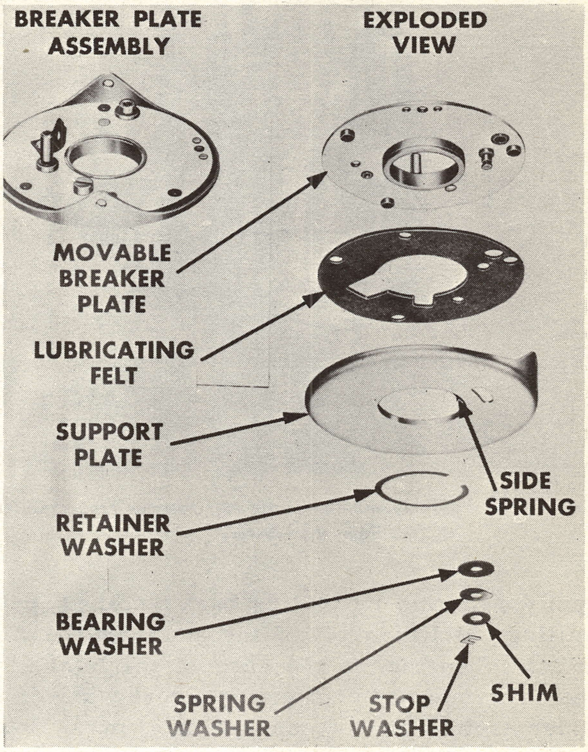
Breaker points must be centered and in accurate alignment, Fig. 35-28. Misalignment of breaker points will severely reduce their life and result in misfiring.

When aligning breaker points, only the stationary point bracket should be bent, Fig. 35-29. Never attempt to bend the movable breaker arm.



35-25. Some types of distributor shaft bushings must be burnished after installation.

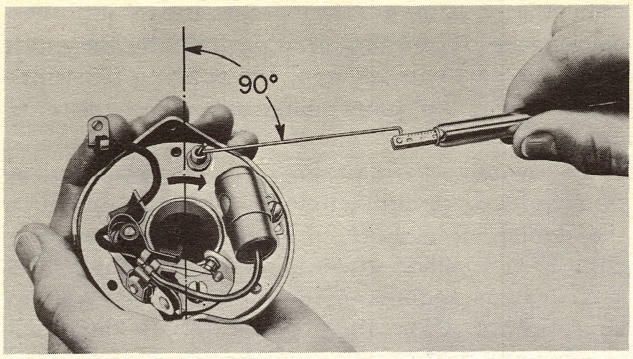
Breaker points are fastened to the breaker plate by means of a lock screw, Fig. 35-30, or the two attaching screws, Fig. 35-31. To remove the breaker point assembly shown in Fig. 35-30, after removing the distributor cap and rotor, remove the screw holding the condenser to the breaker plate, and disconnect the condenser lead together with the breaker arm spring. Remove the lock screw, permitting the lifting up of the point assembly from the pivot post.



35-26. The assembly of the centerbearing breaker plate is shown in the upper left and exploded view is on the right.

In the case of the distributor shown in Fig. 35-31, the procedure is similar except that the contact assembly is held in position by two screws. Note in this design, the breaker points form a single assembly, and according to the manufacturers, there is no need to align the points. The only adjustment required is that of cam dwell (gap).

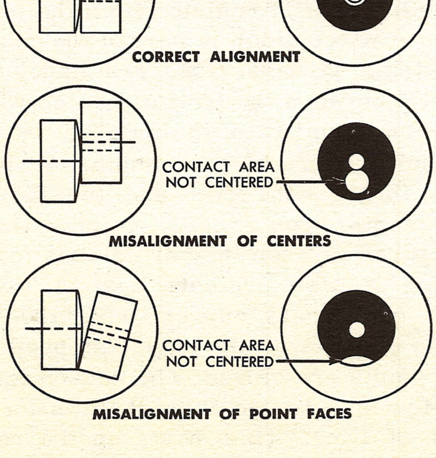
The installation of breaker points or contact point assemblies, is accomplished in the reverse order. To adjust the breaker point gap, or dwell, an eccentric adjustment screw is provided, Fig. 35-30. This moves the position of the stationary point in relation to the movable point, thereby altering the gap between the two. When setting the gap, the rubbing block on the movable arm must be on a high point of the dis-



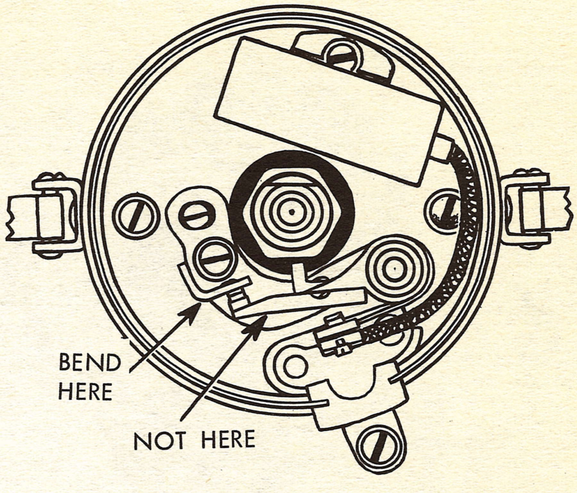
35-27. *Measuring tension on movable plate.*

tributor cam. The gap is adjusted to a specified width. When setting the gap, a blade of a thickness gauge of the correct thickness, is placed between the points and the gap is adjusted by turning the eccentric screw. Instead of an eccentric screw, some distributors have a notched hole in the breaker plate in which a screwdriver is inserted.

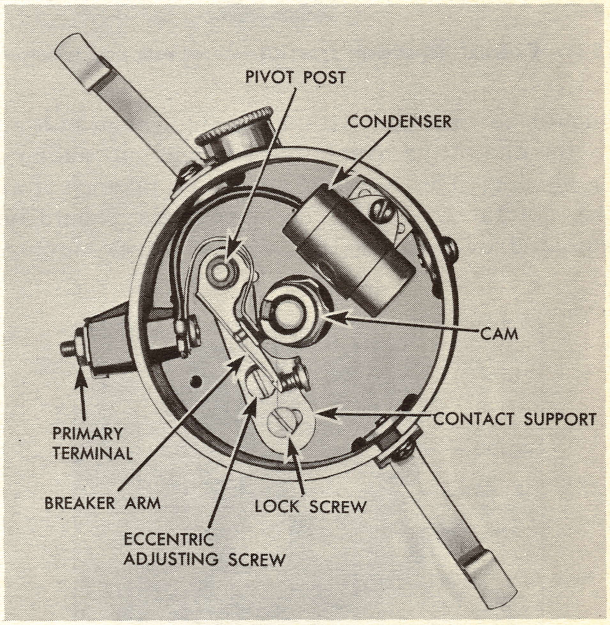
In the case of the distributor shown in Fig. 35-31, the point gap is adjusted by means of screw as shown in the illustration which moves the stationary point backward or forward as required. In that way, alignment of the points is not altered. The adjustment is controlled by inserting an Allen-type wrench into the hexagon hole in the adjustment. This adjustment can be made without removing the distributor cap, as the cap is provided with a window, Fig. 35-32, through which the adjustment can be reached with the Allen wrench. This permits making the adjustment while the engine is running to the specified dwell angle of 30 deg. for an eight cylinder engine. Another method can be used if a dwell meter is not available. Connect a test lamp in series in the primary lead. Rotate the distributor shaft until the rubbing block is on the high point of one of the cams. Then turn adjusting screw, Fig. 35-32, until lamp lights. Then back off on the adjustment one-half turn.


CONTACT AREA
CENTERED
CORRECT ALIGNMENT
CONTACT AREA
NOT CENTERED
MISALIGNMENT OF CENTERS
CONTACT AREA
NOT CENTERED
MISALIGNMENT OF POINT FACES

35-28. *Ignition breaker points must be accurately aligned for efficient operation and long life.*


BEND
HERE
NOT HERE

35-29. *To align ignition breaker points bend only the stationary point bracket. Special bending tools are available for the purpose.*

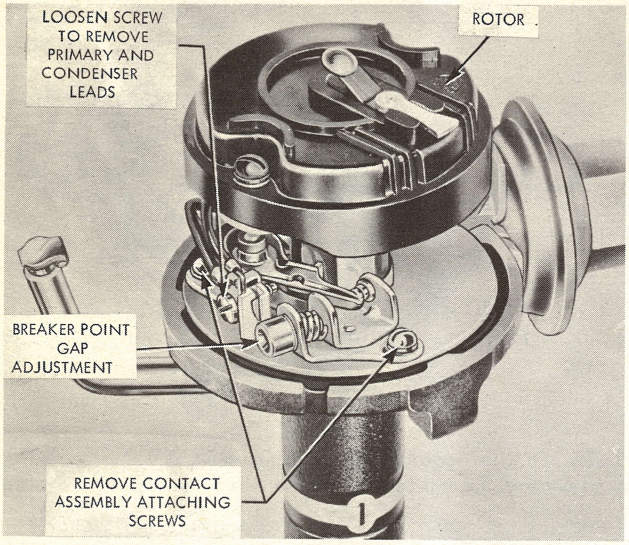

PIVOT POST
CONDENSER
CAM
CONTACT SUPPORT
PRIMARY
TERMINAL
BREAKER ARM
LOCK SCREW
ECCENTRIC
ADJUSTING SCREW

35-30. *Note eccentric adjustment for setting breaker point gap.*

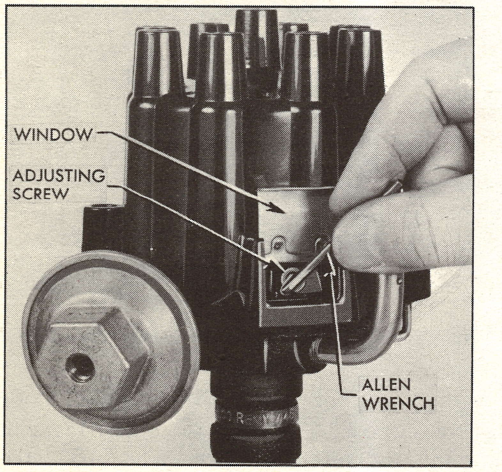
Dirty and slightly pitted ignition breaker points can be dressed with a few strokes of a fine-cut contact point file. The file must be free of dirt and oil. Care must be taken to keep the surfaces of the points parallel. In most cases it is advisable to install a new set of contact points.

Breaker Arm Spring Tension:

Breaker arm spring pressure must fall between specified limits. (Usually 19-23 oz.). Weak spring tension will result in chatter and missing at high speeds, while excessive tension will cause excessive wear of the points, rubbing block and distributor cam. Contact point pressure should be checked with a spring gauge hooked to the end of the breaker lever and pull exerted at 90 deg. The reading should be taken just as the points separate. The pressure should be adjusted by bending the breaker lever spring. To decrease the pressure, pinch the spring carefully, Fig. 35-33. To increase the pressure, the lever must be removed from the distributor, so the spring can be bent away from the lever.


LOOSEN SCREW TO REMOVE PRIMARY AND CONDENSER LEADS
ROTOR
BREAKER POINT GAP ADJUSTMENT
REMOVE CONTACT ASSEMBLY ATTACHING SCREWS
1

35-31. External adjustment type distributor with cap removed.



35-32. Adjusting cam angle, or breaker point gap, on external adjustment type distributor.

Cam Angle:

Cam angle or dwell, as it is also called, is the number of degrees of cam rotation from the instant the ignition breaker points close until they open again. It is controlled entirely by the width of the breaker point gap. Decreasing the width of the breaker point gap, increases the cam angle.

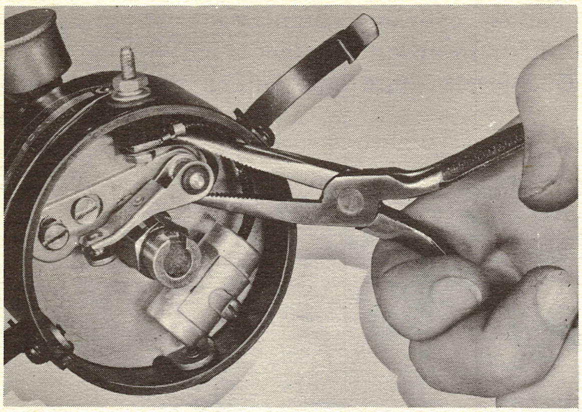
To measure the cam angle, special equipment is required. A cam angle meter is included in the design of a distributor tester as shown in Fig. 35-18. When checking the cam angle, the instructions accompanying the equipment should be followed. Cam angle of six cylinder engines is approximately 40 deg., and for eight cylinder engines approximately 30 deg. However, the specifications for the individual ignition system should be followed.

Ignition Resistor:

In most 12 v. systems and some 6 v. systems, a resistor is connected in series with the primary circuit of the ignition coil during normal operation, Fig. 35-1. However, during the cranking period, the resistor is cut out of the circuit so that full voltage is applied to the coil. This insures a strong spark during the cranking period, and in that way quicker starting is provided. Contacts on the cranking motor solenoid are used to cut the resistor out of the primary circuit during the cranking period. The ignition coil and its windings are designed to operate efficiently at a voltage lower than full battery voltage, so that when full battery voltage is applied, a hotter than normal spark is provided. It must also be remembered, that during the cranking period, the excessive load applied on the battery, will reduce the voltage reaching the ignition system. If full battery voltage was used continually for normal operation, the coil would quickly burn out.

The resistors used in the primary circuit are of two general types. One type is a single unit as shown in Fig. 35-1. When used, it is usually mounted on the fire wall near the ignition coil.

The other type of resistor is in the form of a resistance wire, which is part of the instrument panel wiring harness. This resistance wire is connected between the ignition switch wire, and the positive terminal of the coil. This resistance wire limits to a safe maximum, the primary current through the coil and the distributor contact points, protecting the points during slow speed operation when they are closed for longer intervals. It also protects against excessive build up of primary current when the ignition switch is closed with the engine stopped and the contact points are closed. The reason for this is that at low speeds, the current flows for longer periods of time. This heats up the resistor, thereby raising its resistance and reducing the current flow, with the further result that the coil primary is cooler and breaker point life is improved. At high speeds, the current flows for shorter periods of time, which lets the resistor cool, increasing current flow, to provide maximum spark plug voltage.

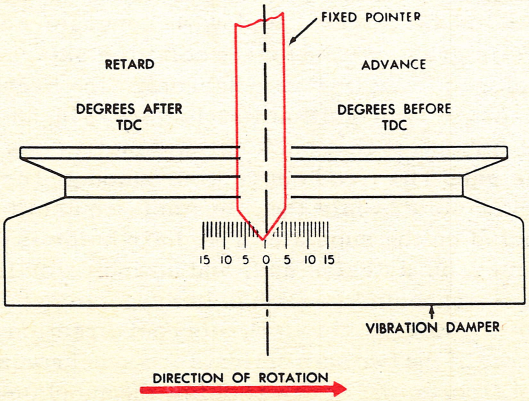


35-33. Illustrating method of decreasing pressure of breaker arm spring.

Resistors and resistor wires should be checked whenever the breaker points are burned or when the ignition coil is burned out. With the ignition switch turned on, the voltage reading from the resistor side of the coil to the ground should be approximately 5 to 7 v., unless other specifications are available. Resistance of resistor as used on 12 v. systems is approximately 1.5 ohms.

IGNITION TIMING

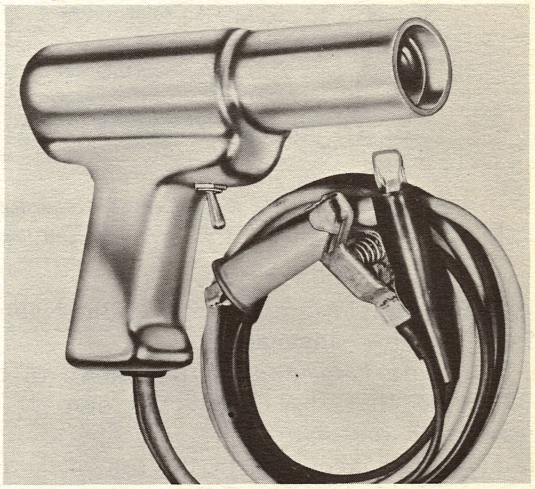
The ignition must be accurately timed so that the spark occurs in the combustion chamber at the correct instant. Incorrectly timed ignition results in loss of efficiency and power. If the spark occurs too early, both fuel economy and power will be sacrificed. If the spark occurs too late, preignition with attendant "pinging" occurs, and if continued, the engine will be damaged. The time that the spark occurs varies considerably in different engines and for that reason factory specifications should be carefully followed. The occurrence of the spark is timed in relation to the position of number one piston, unless otherwise specified, and is listed as so many degrees before top center. This is abbreviated to BTC or BTDC, and the top center referred to, is at the end of the compression stroke.



35-34. Typical of timing marks on vibration damper.

Timing marks are placed on the flywheel, the vibration damper at the front of the engine or on the fan pulley. Typical timing marks are shown in Fig. 35-34.

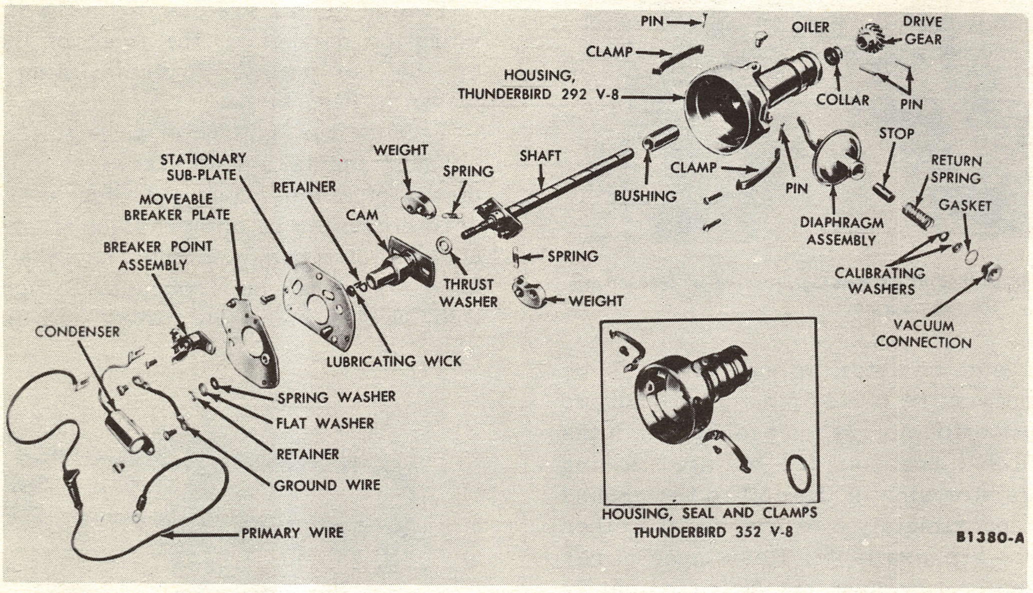
To time the ignition of an engine, the ignition breaker points should just start to open, as the piston of number one cylinder approaches top dead center on its compression stroke. The most accurate method, and the one most frequently used, is to use a stroboscopic type of timing light, Fig. 35-35. The timing light is connected to the battery and to Number One spark plug. The beam is then directed to the timing marks, and with the engine running, the light will flash each time the spark occurs. The timing marks will have the appearance of standing still so that the time the spark occurs is easily noted. The specified timing mark should coincide with the index mark. If not, the clamp screw of the distributor is loosened, and the distributor rotated to the correct position. Moving the distributor housing against shaft rotation advances the timing, and with shaft rotation retards timing.



35-35. Typical power timing light as used for ignition timing.

DISTRIBUTOR TYPES

In addition to the distributors previously illustrated and discussed, there are several others used on vehicles. Fig. 35-36 shows the dual advance distributor used on some Ford engines. On this distributor, centrifugal advance is decreased by bending a spring post (located below the breaker plate) away from the distributor shaft. Vacuum advance on this distributor is controlled by shims placed behind the vacuum diaphragm spring. Adding washers will decrease the advance.


PIN
OILER
DRIVE GEAR
CLAMP
HOUSING, THUNDERBIRD 292 V-8
COLLAR
PIN
STOP
RETURN SPRING
GASKET
STATIONARY SUB-PLATE
WEIGHT
SPRING
SHAFT
CLAMP
BUSHING
PIN
RETAINER
MOVEABLE BREAKER PLATE
CAM
DIAPHRAGM ASSEMBLY
BREAKER POINT ASSEMBLY
SPRING
THRUST WASHER
WEIGHT
CALIBRATING WASHERS
VACUUM CONNECTION
CONDENSER
LUBRICATING WICK
SPRING WASHER
FLAT WASHER
RETAINER
GROUND WIRE
PRIMARY WIRE
HOUSING, SEAL AND CLAMPS THUNDERBIRD 352 V-8
B1380-A

35-36. Details of dual advance distributor used on some Ford engines. This design includes both centrifugal and vacuum advance.

In the Auto-Lite distributor shown in Fig. 35-37, note that the distributor cam is not integral with the shaft, but is a separate unit. A felt wick is provided in the top of the distributor cam for lubrication.

SPECIAL DISTRIBUTORS

The ignition distributors used on most cars have a single set of breaker points and cam lobe for each cylinder of the engine. At higher engine speeds, the breaker points of such distributors remain closed a very short time, with the result that there is very little time for the coil to build up. This difficulty can be overcome to a degree by means of twin ignition distributors or double alternate distributors. Twelve volt ignition is another method of providing a better spark at high speeds and is discussed in another section.

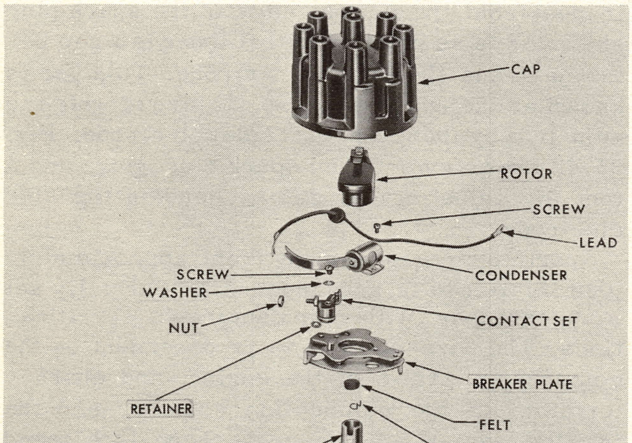
Twin ignition distributors, Fig. 35-38, are built as though they were two complete distributors combined into a single unit. This type has two complete and independent ignition systems--two ignition coils and two sets of breaker points, and two spark plugs for each cylinder. Usually the two sets operate simultaneously so the spark at both plugs in the cylinder occurs at the same instant. However, they can be designed so one set of breaker points opens slightly before the other in order to offset a lag in combustion.

Double alternate distributors, Fig. 35-39, have two breaker arms that operate alternately. This permits a cam to be used that has half as many lobes as there are cylinders. In some installations the two sets of breaker arms are connected to a single ignition coil, while in other cases, two coils and a special cap and rotor are used. In that way, each set of contacts remains closed for a longer interval and with separate coils, there is greater time for the coil to be saturated.

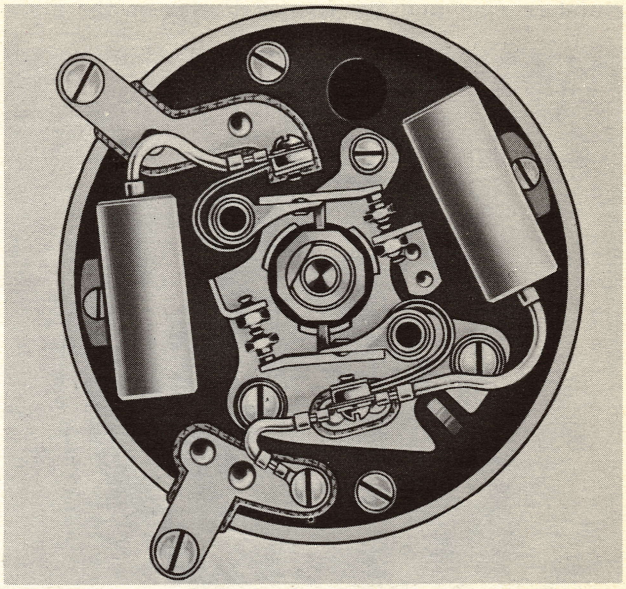
Before attempting to synchronize the breaker contacts of twin ignition distributors, Fig. 35-38, it is important that each set of contacts has the same gap. The fixed contacts are mounted on the breaker plate, while the adjustable contacts are mounted on the subplate. The distributor is then mounted on a test stand, and an indicator light lead is connected to each primary terminal. Operate the distributor in the correct direction and observe if the two sets of lights are synchronized. If not, loosen the screws holding the subplate and rotate the subplate until the two lights are exactly synchronized.

The double alternate distributor with 45 deg. spark, Fig. 35-39, has one set of contacts on the mainbreaker plate assembly and another set of contacts on the subplate. The first step in synchronizing the breaker points is to set the gaps exactly the same. The assembly is then mounted on a test fixture and when operated there should be a 45 deg. interval between the opening of one set of contacts and the opening of the other. Adjustment can be made by adjusting the position of the subplate which is controlled by an eccentric.

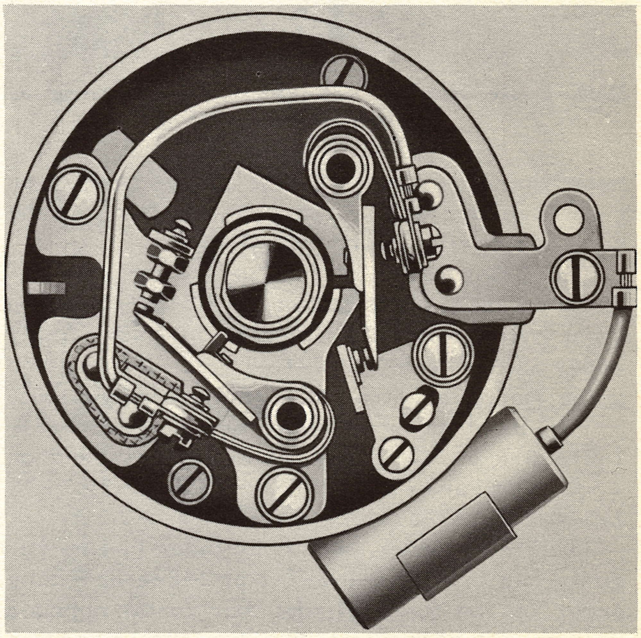
The distributor shown in Fig. 35-40 is similar to that shown in Fig. 35-39, except that two coils are used and the breaker contacts are not 45 deg. apart. The interval between the contacts varies with the angle of the V of the engine cylinders. A test fixture is required when synchronizing the breaker points of such a distributor. As in the other types of distributors, both sets of contact points are adjusted to the same specified gap. Then with the distributor mounted in a testing fixture, the subplate is adjusted to obtain the firing interval specified for that particular distributor.


CAP
ROTOR
SCREW
LEAD
SCREW
WASHER
CONDENSER
NUT
CONTACT SET
RETAINER
BREAKER PLATE
FELT
SNAP RING
CAM
SEAL
GOVERNOR WEIGHT
SPRING
SHAFT
WASHER
BEARING
SPRING
SCREW
BASE
SCREW
SCREW
VACUUM CONTROL
BEARING
WASHER
SCREW
SPRING
COLLAR
PIN
61x109

35-37. *Auto-Lite distributor used on Plymouth V-8.*



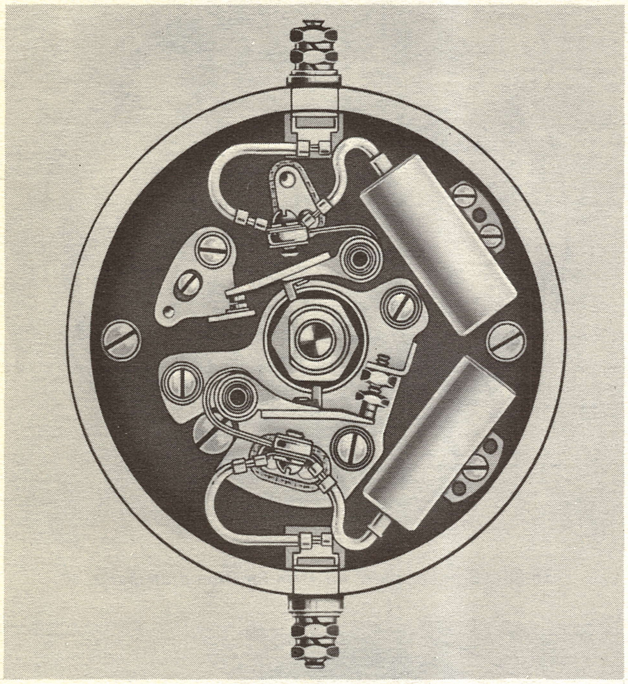
35-38. *Breaker plate for twin ignition distributor.*



35-39. *Breaker plate for double alternate distributor using a single coil. (Auto-Lite)*

FIRING ORDER

In order to reduce engine vibration and secure an even flow of power, the cylinders of internal combustion engines must fire in the correct sequence. When describing the firing order of different engines the cylinders are numbered. On in-line engines Number One cylinder is the one immediately behind the timing gears, the remaining cylinders are in numerical order. On V-8 engines, the usual practice is to call the first cylinder on the left bank Number One and the first cylinder on the right bank would be Number Five in the case of an eight cylinder engine, or Number Seven in the case of a twelve cylinder engine.



35-40. *Breaker plate for double alternate distributor using two ignition coils. (Auto-Lite)*

The firing order of in-line six cylinder engines in the United States is 1-5-3-6-2-4. On eight cylinder in-line engines the usual firing order is 1-6-2-5-8-3-7-4. The Dusenberg and some European straight eights are exceptions.

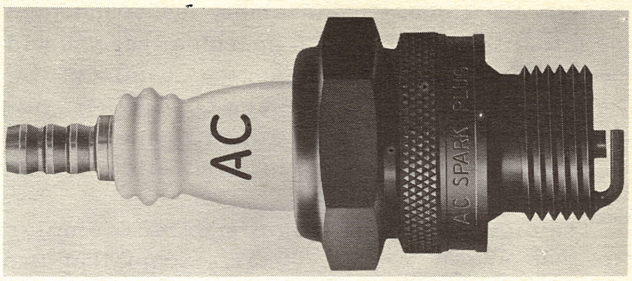
The most popular firing order of a V-8 is 1-8-4-3-6-5-7-2. Other firing orders used on V-8 engines are: 1-6-2-5-8-3-7-4, 1-5-4-2-6-3-7-8, and 1-8-7-3-6-5-4-2.

The firing order of four cylinder in-line engines can be either 1-3-4-2 or 1-2-4-3. Firing order on the four cylinder horizontal opposed Volkswagen engine is 1-4-3-2, with Number One cylinder being marked on the rim of the distributor.

SPARK PLUGS

The spark plug in a spark ignition engine provides the gap across which the high tension voltage jumps, creating a spark which ignites the compressed mixture of air and fuel.

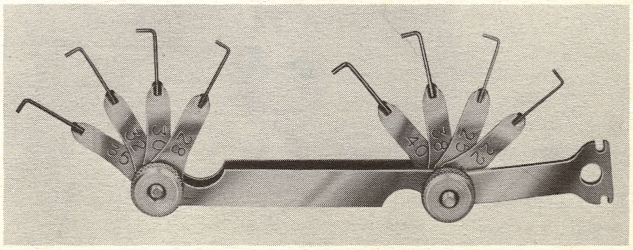
The spark plug, Fig. 35-41, consists of a central electrode which is connected to the ignition coil secondary through the distribuutor. The central electrode is insulated from the spark plug shell by means of a molded insulator resembling porcelain. The side electrode protrudes from the bottom edge of the spark plug shell and is so positioned that there is a gap between it and the center electrode. This gap is known as the spark plug gap, the size of which is adjusted by bending the side electrode. Fig. 35-42 shows a combined spark plug gauge and a tool for adjusting the gap by bending the side electrode.



35-41. *A spark plug manufactured by the AC Spark Plug Division of General Motors Corporation.*

Spark plug gaps range from approximately .020 in. to .040 in. and they must be carefully set in accordance with manufacturer's specifications. The size of the gap is dependent on the compression ratio of the engine, and characteristics of the combustion chamber and the ignition system. In general, there is a trend toward wider spark plug gaps made possible by improved ignition systems. At one time a gap of .025 in. was virtually standard on all engines. Today, however, many manufacturers specify gaps of .030, .035 or .040 in. The advantage of the wider gap is that it includes more mixture than a narrow gap and consequently there is better opportunity to ignite it.

The shell of the spark plug is threaded so it can be easily replaced. The following thread sizes are used: 1/2 in. pipe thread, 7/8 in., 10



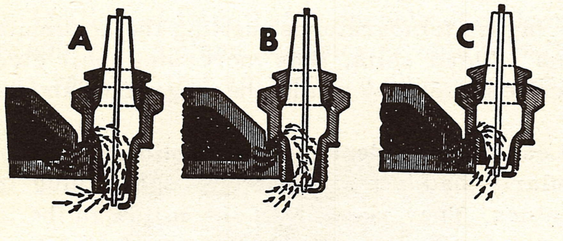
35-42. *Spark plug gap gauge, with gap adjuster at right end. The various gauges are of the wire type for more accurate measurement of the gap.*

mm., 14 mm., and 18 mm.

The 1/2 and 7/8 in. sizes are now obsolete in the automobile field, but are still used on some engines in the marine field.

Currently in automobile engines, the usual sizes are 14 and 18 mm.

In addition to having the correct size thread, it is important that the spark plug extend into the combustion chamber the correct amount. The correct point for the spark plug electrodes in the combustion chamber is determined by the engine manufacturer. Installing plugs with a longer reach than specified will place the electrodes further in the combustion chamber. This may result in the valves or piston striking the spark plug. If a plug with a short reach is installed so that the spark plug electrodes become partly sheltered by the spark plug hole in the cylinder head, engine roughness and missing will probably result.



35-43. *Illustrating the path that heat must take from the tip of the spark plug to reach the water jacket of the engine. The longer the path, the hotter the plug. Spark plug (A) is a hotter plug than plugs (B) or (C).*

HEAT RANGE

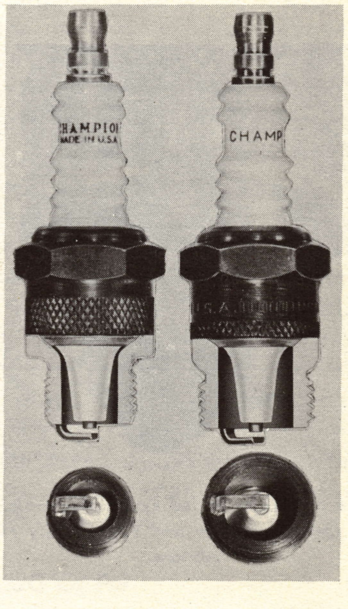
Spark plugs must be designed so the temperature of the firing end of the plug is high enough to burn off any carbon or other combustion deposits. But it must not get so hot as to cause preignition or deterioration of the insulator or electrodes. This is difficult as the temperature of the spark plug tip varies greatly with different engines and with different operating conditions. W. A. Bychinsky, chief ignition engineer of the AC Spark Plug Division of General Motors Corp., points out that in conventional automotive service, the center wire temperatures range from a low of 200 degs. C. at 10 m.p.h. to a high of 800 degs. C. at 80 m.p.h.

The temperature of the spark plug insulator is dependent on the characteristics of the spark plug itself and also on the burning fuel in the combustion chamber. The latter temperature will of course vary with the design of the engine, compression ratios, cooling system, and air-fuel ratio.

As the tip of the spark plug absorbs heat from the burning fuel, the heat travels up the insulator to the spark plug shell, to the cylinder head, and then to the water jacket. The path the heat travels is shown in Fig. 35-43. The heat absorbed by the insulator increases as the temperature in the combustion chamber increases. More heat will be absorbed as the area of the insulator exposed to the hot gases is increased. More heat will be absorbed by the spark plug shown on the left of Fig. 35-43, than the one on the right as the area of its tip exposed to the combustion chamber is greater.

If the path the heat must follow to reach the cooling system is short, the tip will have a lower temperature than if the path is long. Plugs with long paths for the heat to travel are known as hot plugs, while spark plugs with short paths for the heat to travel are known as cold plugs.

In addition to the length of the path traversed by the heat in reaching the cooling system, the material of which the insulator is made and also its shape will affect its temperature. As a result, some spark plug insulators have a narrow neck just above the tip. Another design will have recessed tip sections which more readily follow temperature changes in the combustion chamber. Other designs provide increased volume between the shell and the insulator which permits more effective charge cooling, Fig. 35-44. Another design has the tip of the insulator protruding beyond the end of the shell for improved heat characteristics.



35-44. *Comparison of new type plug (right) with older type. Note increased volume between insulator and shell.*

Engine designers select spark plugs which will give good performance for average driving conditions. However, if the engine is operated for long periods under approximately full load conditions, the standard equipment spark plug will operate at too high a temperature and preignition will result. It is, therefore, necessary to install a colder plug, which will carry off the greater heat more rapidly.

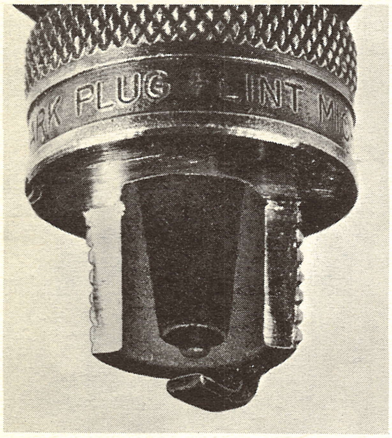
On the other hand, if the engine is operated for long periods of slow speed at part throttle opening, the standard equipment plug will tend to foul. That is, the insulator tip will become covered with carbon and other products of combustion. The result will be that the high tension voltage will leak across the accumulations (because of their lower resistance) rather than jump the gap at the electrodes. A hotter plug (one with a longer heat path) should then be used.

SPARK PLUG FOULING

As pointed out in the preceding paragraphs on "Heat Range," there is a tendency for products of combustion to accumulate on the portion of the insulator of the spark plug within the combustion chamber. As a result there are three types of spark plug fouling:

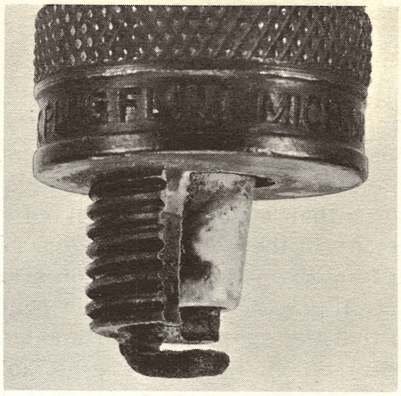
1. Carbon fouling
2. High speed or lead fouling
3. Oil and carbon fouling

Carbon fouling, Fig. 35-45, results primarily from extended low speed operation and when the carburetor mixture is excessively rich. Carbon fouling is usually relatively soft black soot which is easily removed from the spark plug and causes missing or roughness.



35-45. Example of carbon fouled spark plug which results from prolonged low speed operation and excessively rich carburetor mixture.

Lead fouling, Fig. 35-46, results from the tetraethyl lead used in the fuel to improve its anti-detonating characteristics and is caused by extended high speed operation. Spark plugs with lead fouling will frequently operate satisfactorily at low and medium loads. But when full load is applied, missing will occur. This results from the higher temperatures melting the accumulations of lead salts, thus increasing their electrical conductivity so that the plug will be shorted out.



35-46. High speed or lead fouling results from the fuel additives and prolonged high speed driving.

Lead compounds added to gasoline have a particularly bad effect on some spark plug insulators. They react with the silica in the insulator to form lead silicate glass which has a low melting point, and which at high temperatures, is a relatively good conductor of electricity. For that reason a spark plug may give satisfactory operation under light loads, but fail when full loads and high combustion chamber temperatures are reached.

In some cases of lead fouling, it is possible to operate the engine at a speed just below the point where missing will occur. Then by gradually increasing the speed (always keeping below the missing speed) it will be possible to burn off the lead fouling and full throttle operation attained.

Lead fouling will sometimes appear as a heavy crusty formation; in other instances it will be tiny globules. The form it takes will depend on fuel, operating conditions and time.

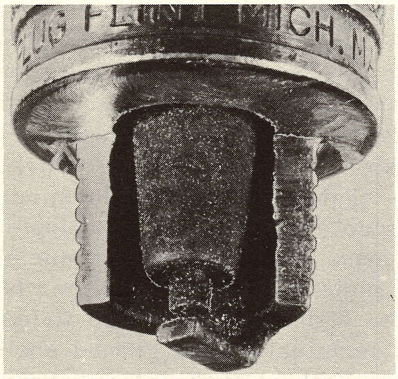
The third type of fouling, Fig. 35-47, is found on engines that are badly worn so excess oil reaches the combustion chamber, either past the piston rings or past the valve guides.

Another condition that affects spark plug operation is the condition of the gap across which the spark jumps. In Fig. 35-48 is shown a spark plug with extreme electrode erosion resulting from the plug having been used too long. High capacity of the system also affects electrode life. (See paragraph on spark plug gaps).

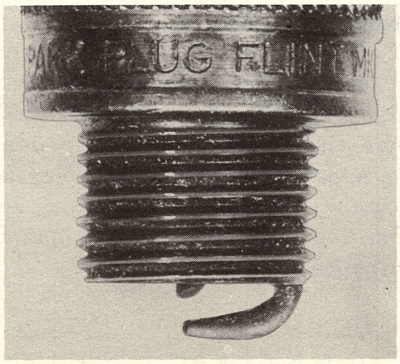
VOLTAGE REQUIRED TO JUMP GAP

There are many factors which will affect the voltage required to jump a certain gap. Among these factors may be included the shape of the electrodes forming the gap, the conductivity of the gases in the gap, temperature, pressure, and the air-fuel ratio existing within the gap. W. A. Bychinsky of the AC Spark Plug Division of General Motors Corp., gives the data shown in Fig. 35-49. It will be noted that the voltage required to jump a gap increases rapidly until 12,000 v. is needed to jump a gap of .060 in. The measurements were made in a conventional automotive engine at road load.

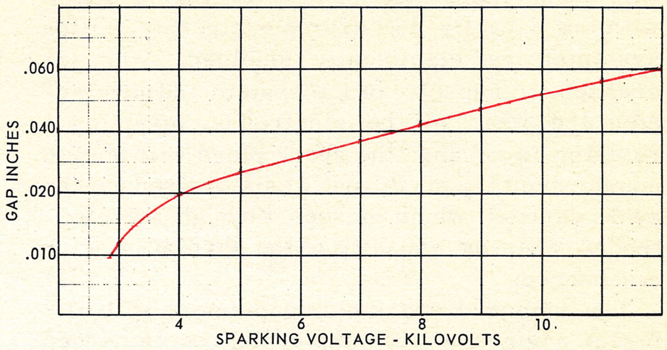
As pointed out in the section on distributors, the current delivered to the plugs is dependent on the current flowing in the primary, and this decreases as the engine speed increases. The voltage at the plug is also dependent on the cleanliness of the spark plug electrode. For example, an ignition system that is capable of delivering 20,000 v. to a clean plug may be able to deliver only one half that amount to a plug that is partly fouled. This results from the fact that it takes appreciable time for the voltage to build up to a value where it can jump the plug gap. This is explained as follows: When the ignition breaker points are closed, energy is stored in the ignition coil in the form of the magnetic field. Then when the breaker points open, the magnetic field collapses, causing the high voltage. This high voltage is not reached instantaneously, but it is built up to a maximum and then drops to zero. This requires an appreciable length of time (electrically speaking) or about 1/20,000 second. Thus, the voltage increases until it reaches such a value that it is capable of jumping the gap at the spark plug. However, if the plug is partly fouled, some current will flow across the coating on the insulator. In other words, the accumulation on the insulator acts as a shunt across the gap. This loss of current reduces the peak voltage so that in the case of a badly fouled plug the voltage may not build up to a value that will jump the gap.



35-47. ***Example of oil and carbon fouling which results from excess oil reaching the combustion chamber.***



35-48. ***Abnormal erosion of electrodes results from extreme plug temperatures. Make sure that plug has correct heat range and that plug is seated firmly on new gasket.***



35-49. ***Voltage required to jump different size gaps.***

W. A. Bychinsky points out in a paper presented before the Society of Automotive Engineers that the faster the high tension voltage is built up, the less effect fouling will have. One method of attaining fast electrical build-up condition is by means of high frequency ignition systems. Another is by means of a series gap. However, the construction of reliable series gaps is difficult, but considerable progress is being made in that direction.

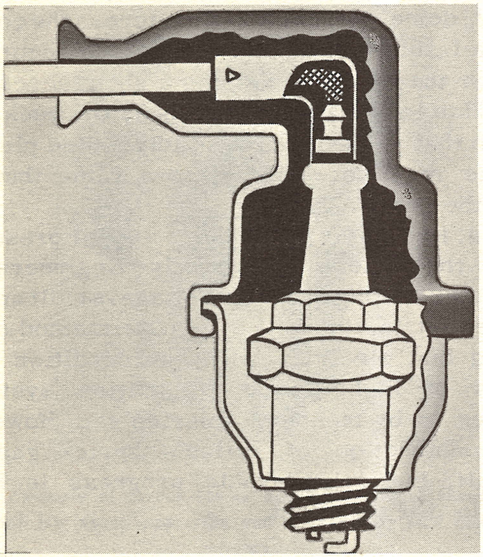
SPARK PLUG GAPS

Spark plug gaps do not remain constant, but increase in size, the amount of increase being dependent on mileage, chemical characteristics of the fuel, combustion chamber temperatures, and particularly the action of the electrical spark which tears off portions of the electrode. The electrical characteristics of the ignition system also affect the rate of wear of the spark plug electrodes. In this connection, the electrical capacity of the ignition coil and the wiring is an important factor. Systems with high capacity will cause more rapid gap wear than systems with low capacity. For example, aircraft ignition systems are electrically shielded. This increases the capacity of the system and accelerates the wear of the electrodes. Inserting a resistor in or near the spark plugs will tend to counteract this condition. Resistors reduce the peak current which passes through the electrodes when the capacity of the system is being discharged.

The standard spark plug gap varies with different engines. For example, the recommended gap on many American cars is .035 in., while on European cars it is often less than .025 in.

Experimentally it has been determined that the combustion process in an engine is independent of the spark. In other words, if a spark is obtained at the plug gap, it will ignite the mixture and the minimum amount of energy required in the spark to start combustion is only a small part of the total energy available.

However, in actual practice some engines operate better with wider spark plug gaps than others and many engineers are in agreement that the explanation is in the characteristics of the air-fuel mixture in the vicinity of the plug gap. The air-fuel mixture in different parts of the combustion chamber of different engines varies considerably. This is due to the form of the combustion chamber, the turbulence imparted to the mixture, and the amount of burned gases remaining in the combustion chamber from the previous cycle of operation.



35-50. Spark plug insulator and terminal protected by special nipple.

INSTALLATION OF SPARK PLUGS

Before installing a spark plug, it is important to make sure it is clean (if a used plug is being installed) and that the gap is adjusted in accordance with the manufacturer's specifications. When adjusting the gap, the side electrode only should be bent. Never bend the central electrode, as that will crack the insulator.

After adjusting the gap, make sure the threads of both the spark plug and the threads in the engine are clean, and not encrusted with carbon and dirt. Also clean the surface of the cylinder head against which the spark plug gasket seats. This is important, for if dirt is present at that point, compression leaks may occur, and in addition, the dirt acts as a heat insulator and the spark plug will run hot and faulty operation result.

When tightening a spark plug, a torque wrench should be used. While most spark plugs should be tightened to 25 to 30 ft. lbs. torque, there are many exceptions and the manufacturer's specifications should be consulted. Spark plugs should be tightened only to the degree that the gasket is just crushed. When spark plugs are replaced, new gaskets should always be used.

The external portion of the spark plug insulator, together with the terminal, should always be covered with a rubber nipple made for that purpose. This prevents accumulation of dust and moisture on the insulator which would permit the high tension voltage to leak across from the terminal to the ground shell or body of the plug. Without such nipples secondary voltage is greatly reduced. A spark plug and terminal protected with a special rubber nipple is shown in Fig. 35-50.

CLEANING SPARK PLUGS

Special equipment is available for cleaning spark plugs, such as shown in Fig. 35-51. However, when the spark plug electrodes become worn, the spark plugs should be replaced as it takes a higher voltage to jump across worn electrodes even though the gap has been adjusted to the correct size.

SPARK PLUG LIFE

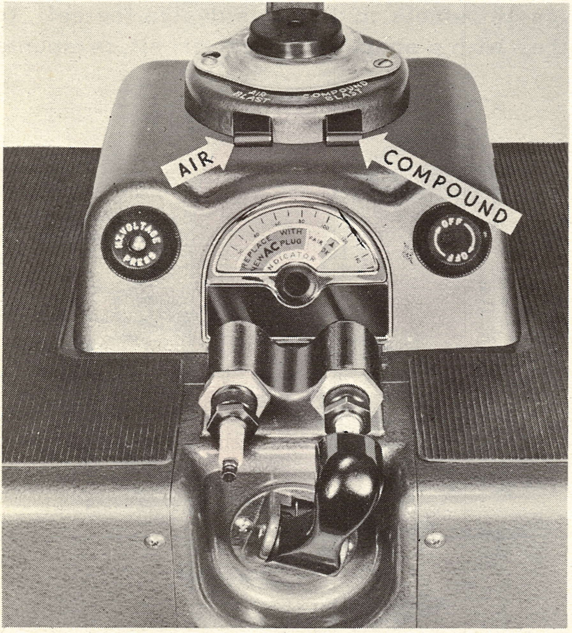
Under favorable operating conditions, the life of a spark plug ranges from 5,000 to 10,000 miles. Beyond that mileage, they should be replaced.

Steadily raising compression ratios and increased quantities of tetraethyl lead in the fuel to raise its octane ratings, have made the conditions under which the spark plug operates increasingly severe.

Spark plug life can be materially extended by frequent cleaning and regapping. As the electrodes become worn, they should be filed until the end of the center electrode is flat and smooth, and the surface of the side electrode is parallel to the end of the center electrode. Higher voltages are required to fire a spark plug with worn electrodes. As shown in Fig. 35-52, considerably higher voltage is needed to fire a used spark plug than a new plug. This is particularly true at low speeds where the difference may be as much as 4000 v.

TESTING SPARK PLUGS

Fig. 35-51 shows a combined spark plug cleaner and tester. In this unit, the plug is cleaned by blasting the firing end with an abrasive compound. The ability of the plug to fire is then tested under compression.

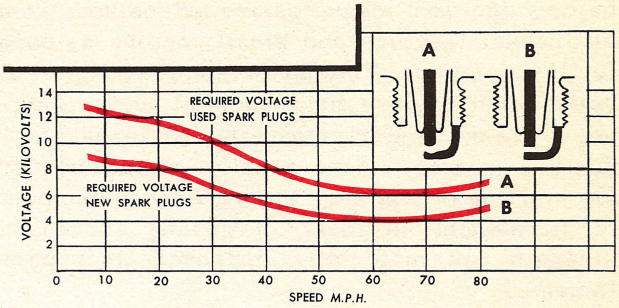


35-51. *Combined spark plug cleaner and tester.*

The tester or analyzer shown in Fig. 35-53 is of the oscilloscope type and is connected to the ignition circuit. Then with the engine running, the behavior and operation of the spark plug is shown on the screen of the oscilloscope. Pictures are provided on the instrument so that comparison can be made of the plug being tested with specific conditions.

MAGNETOS

A magneto is a self-contained device which generates and distributes electricity for igniting the combustible mixture in the combustion chamber of the internal combustion chamber. The magneto not only generates the electricity, but it also steps up the low voltage to a high tension voltage and distributes it to the various cylinders at the correct instant. It does this without the aid of a battery. Some magnetos are of the low tension type, generating a low voltage which is then stepped up to a high voltage by means of a separate coil. High tension magnetos produce voltage of sufficient value to jump the spark plug gap without any external coil.



35-52. *Comparison of voltage required to fire new and old plugs.*

MAGNETO IGNITION ADVANTAGES

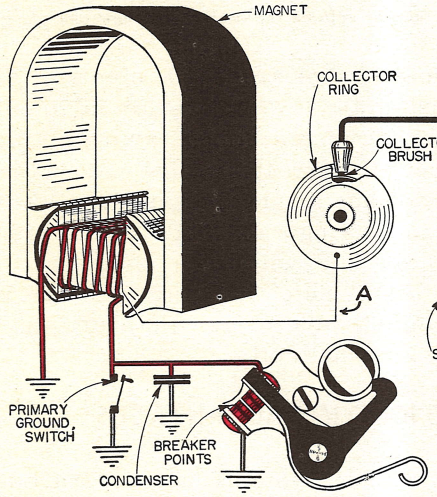
Magneto ignition systems have several advantages. First of all they do not require any battery or other source of current. Secondly, the intensity of the generated voltage does not de-

AC
ACILLOSCOPE SPARK PLUG ANALYZER
ACILLOSCOPE CONNECTIONS

35-53. *Special oscilloscope type spark plug tester, which checks operation of plugs in the engine.*

crease with the engine speed, but increases.

Magnetos were used extensively on automobiles during the early years of the industry, but they have been superseded by battery ignition, one reason being that to start an engine that is equipped with a magneto, relatively higher speeds are required than is the case with battery ignition. Magnetos are extensively used on trucks, tractors and small motors as used for lawn mowers. They are also used on internal combustion engines for industrial power. Magnetos are particularly popular for internal combustion engines, where a battery is not needed for starting or lighting. The recent development of permanent magnets of greatly increased strength has materially improved their performance.



35-54. Diagram of shuttle wound high tension magneto. The lead to the high tension winding on rotor is shown at A.

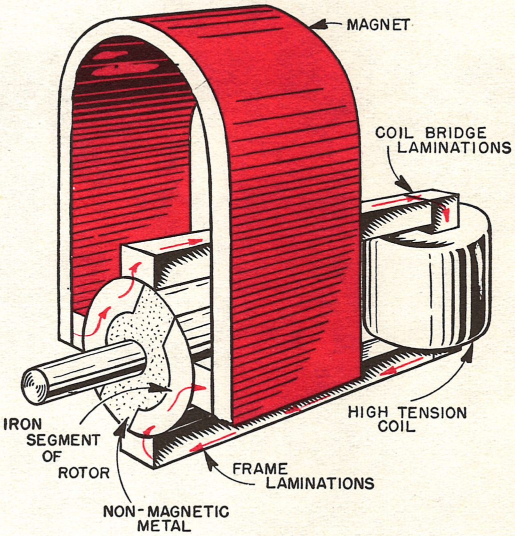
PRINCIPLES OF OPERATION

As previously pointed out in the section devoted to the fundamentals of electricity, electricity can be generated by revolving a coil of wire in a magnetic field. In the conventional generator, the magnetic field is produced by passing some of the generated current through coils of wire (field coils) which in turn produce the magnetic field. In other words, the magnetic field is produced electrically. In the case of the magneto, the magnetic field is produced by means of permanent magnets. Until recently the magnets used in magnetos were made of high quality carbon steel. In approximately 1935, special alloy steels were developed which have greatly improved magnetic characteristics over the carbon steel formerly used. Magnets made of such special alloys are not only stronger for the same size, but also retain their magnetism for much longer periods. The alloys used on modern magnets are usually tungsten, chromium and cobalt.

TYPES OF MAGNETOS

There are two ways in which magnetos may be classified. Originally they were classified as to the type of current they produced---low tension or high tension. The low tension magneto developed a low voltage and required an external coil to step up the voltage. The high tension magneto incorporated the coil in the magneto itself.

The other method of classifying magnetos takes into consideration the portion of the magneto which is revolved. Magnetos which have the windings on an armature which is revolved in a magnetic field are known as shuttle wound magnetos, Fig. 35-54. In the inductor type magneto, both the coil and magnet are mounted in stationary positions and movement of the magnetic field is obtained by breaking and re-establishing the magnetic field, Fig. 35-55. The third type of magneto is known as the revolving magnet design. This has been made possible by the new magnetic steels and in this design the coil, together with a short magnetic circuit, is mounted in a stationary position and one or more magnets are revolved between the pole pieces of the magnetic circuit. Some manufacturers also classify this construction as the induction type.



35-55. Rotory inductor type magneto.

LOW TENSION MAGNETOS

The low tension magneto was the first type of magneto and is still used extensively on industrial engines. In this construction the permanent magnets are U-shaped, with the armature, carrying a single primary winding, revolving between the pole pieces.

As explained in the section devoted to the fundamentals of electricity, revolving a coil of wire in a magnetic field will cause current to flow in the coil, and this current is of the alternating type. The armature winding is connected to the primary winding of an ignition coil, and breaker points which revolve with the armature are timed to open the circuit at peak voltage. This interruption of the primary current produces a high tension current in the secondary winding of the coil (see ignition) which is carried back to the distributor rotor on the magneto where it is directed to the proper spark plug.

Breaker points on a low tension magneto can be connected either in series with the armature winding or in parallel. In the series connection, the magneto serves simply as a current source and the value of the current is relatively low, because the resistance of the primary winding of the coil is included in the circuit. However, when the breaker points are in parallel with the armature winding, a heavier current flows through the armature as the resistance of the primary winding of the coil is no longer included in the circuit. Then when the breaker points open, this heavy current surges through the primary winding of the coil, with a strong inductive effect. The result is that the magnetic field of the coil is built up very rapidly.

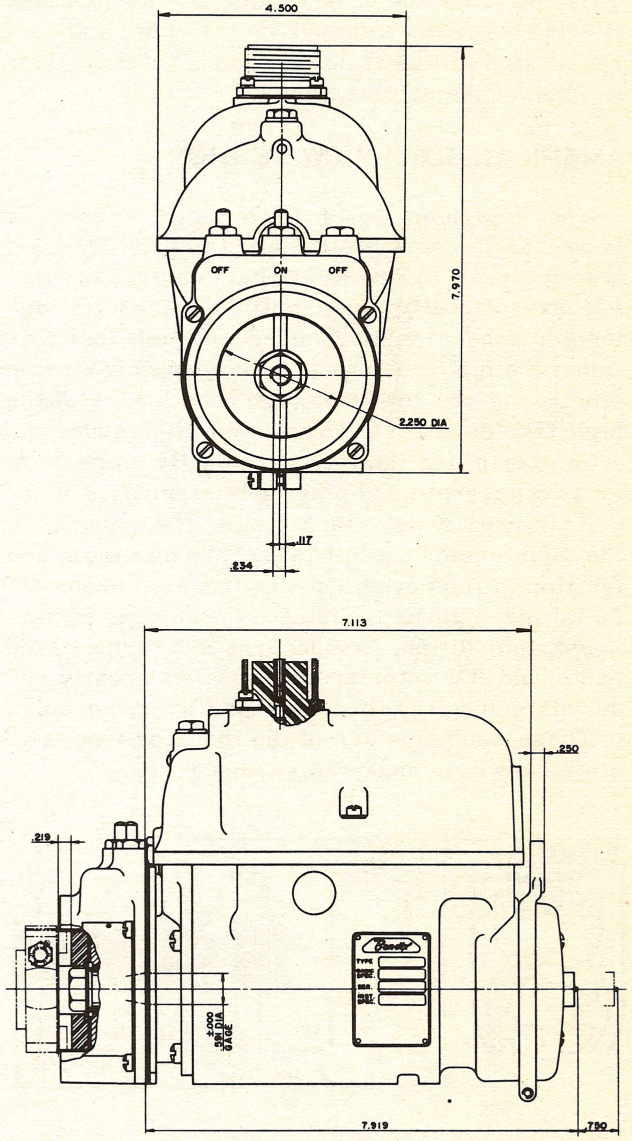
Examples of low tension magnetos in current use are the Bendix L A and L A R magneto made by the Scintilla Magneto Div. of the Bendix Aviation Corp., and the series M R B magneto produced by the American Bosch Corp.

BENDIX LOW TENSION MAGNETOS

The Bendix Scintilla low tension magnetos are of the rotating magnet type and are designed to generate and distribute low tension voltage through low tension cables to individual coils, one located adjacent to each spark plug. The current is stepped up to a high voltage by the individual coils and then conducted to the spark plug by a short length of high tension cable at the proper firing interval of the cylinder. The L A and L A R series magnetos, Fig. 35-56, are of the base mounted type and are available for 2, 3, 4, 5, and 6 cylinder engines. The L A R magneto is equipped with an electrical connector mounted in the cover and containing seven socket connections to simplify and speed installation.

The principle of operation is as follows: The two pole rotating magnet has a North and South pole and magnetic flux passes from the North pole through the coil core and back to the South pole. As the magnet is turned, the polarity continually changes, thereby producing flux reversals in the coil core. The number of flux reversals during one complete revolution is equal to the number of poles on the magnet.

Rotation of magnet (A), Fig. 35-57, causes flux changes in the magneto coil core. These in turn generate low tension current in the magneto coil



35-56. Details of Bendix type L A R low tension magneto.

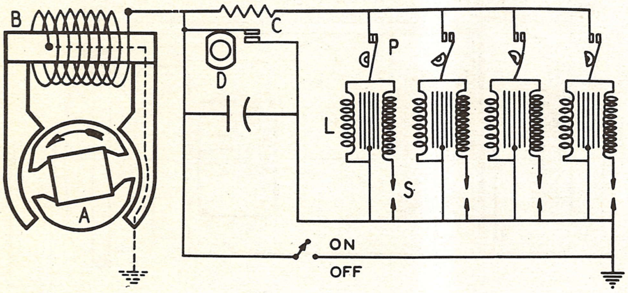
(B). At the position of the magnet, where this current is greatest, the breaker contacts (C) are opened by the cam (D). This causes the current to seek a new path by way of a 1 ohm resistance wire (used to reduce point arcing) to the distributor contact points (P) and the primary winding of the external coil (L) which is mounted adjacent to the spark plug (S) on the engine. Note that Fig. 35-50 applies to a four cylinder application. The rapid rise in current through this winding induces a high voltage in the secondary winding of the external coil (L), causing a spark to jump the gap at the spark plug (S).

The ground terminal on the magneto is electrically connected to the ignition switch. When the switch is in the "OFF" position, this wire provides a direct ground for the primary current. This prevents the interruption of the primary current when the contact points open, and as a result high voltage is not induced in the secondary winding of the external coil.

AMERICAN BOSCH LOW TENSION

The American Bosch low tension magneto is known as the series MRB and is of the shielded type for use with large stationary engines requiring exceptionally long ignition cables. If high tension magnetos were used on such installations, the high tension cables would be of extreme length and the resulting high capacitance of the high tension circuit would seriously reduce the efficiency of the ignition system. By using a low tension magneto and placing the ignition coil or coils close to the spark plugs, the capacity of the high tension circuit is kept at a minimum and ignition is improved. Energy losses, corona effects and high capacitance charges are eliminated. In addition, fire hazards are reduced, and radio and TV interference is also greatly reduced. Spark plug life is materially extended.

These magnetos are of the inductor type, with stationary coil, magnets and breaker.



35-57. Diagram of Bendix Scintilla low tension magneto circuit types L A and L A R.

HIGH TENSION MAGNETOS

The high tension magneto differs from the low tension magneto in that it generates high tension electricity within itself and distributes it to the various spark plugs. No external ignition coil is used, as in the case of the low tension magneto.

In the conventional high tension magneto, the armature is wound with primary and secondary windings, corresponding to the windings of an ignition coil, Fig. 35-6. These windings on the armature revolve in the magnetic field set up by permanent magnets. As the coils or windings pass through the magnetic field, current is generated, and when it reaches its maximum, the breaker points (shunted across the primary winding) open. This induces a current in the secondary windings. As there are more turns of wire in the secondary than in the primary, the voltage is increased in value. The end of the secondary is connected to a collector ring. From there the high tension voltage passes to a distributor and from there to the individual spark plugs.

A variation of the original high tension magneto, in which the coil, condenser and breaker points were rotated, is to rotate a portion of the primary winding, while the remainder of the primary, together with the secondary, contact points, and condenser are stationary. The rotating portion of the primary is wound on the armature and is connected through a collector ring to the stationary primary. The primary circuit is completed through the breaker points to the ground.

High tension magnetos are provided with a safety gap which is shunted across the terminal of the high tension winding and the ground. In this, the insulation of the secondary winding is protected from excessive voltage, which would occur if a wire should become disconnected from a spark plug and there would be an incompleted circuit. A spark would then occur at the safety gap, and excess strain on the secondary insulation would be avoided.

ROTARY INDUCTOR MAGNETOS

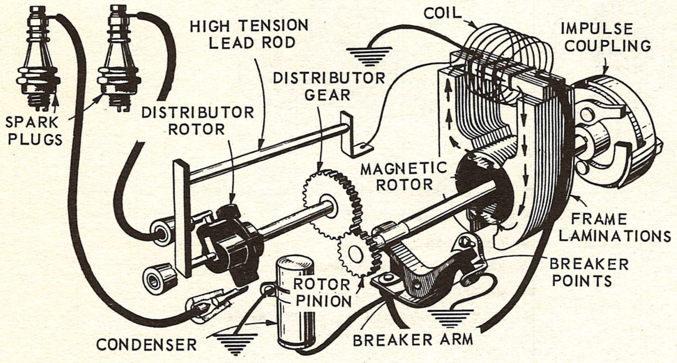
In the rotary inductor type magneto, Fig. 35-55, both the magnet and coil are stationary and current is induced in the primary winding by rotating one or both legs of the magnetic circuit. When only one leg of the magnetic circuit is broken, the magnetic flux in the coil alternates from maximum to minimum, but does not undergo complete reversal when both legs of the magnetic circuit are interrupted.

ROTATING MAGNET MAGNETOS

The introduction of the more powerful permanent magnets of special alloy steel made possible the design of magnetos in which the magnet was revolved. Such magnetos are known as rotating magnet magnetos, and have virtually replaced the original design with stationary U-shaped magnets.

In the rotating magnet design, the coil, condenser and breaker points are stationary with the result that the design is simplified, of more sturdy construction, and moving connections are eliminated. In addition, tests and repairs are more easily made. Smaller and more compact units are also made possible with reduction in cost.

A schematic drawing of a rotating magnet magneto is shown in Fig. 35-58. Rotation of the magnetic rotor produces an alternating magnetic flux or field which cuts the stationary primary winding each time it increases and decreases. As a result, alternating electric currents are induced in the primary circuit during the period the circuit is completed through the closed breaker points. As the density of the magnetic field varies, the strength of the current induced in the primary circuit also varies and reaches a maximum value each time a complete magnetic flux reversal occurs in the magnetic circuit.



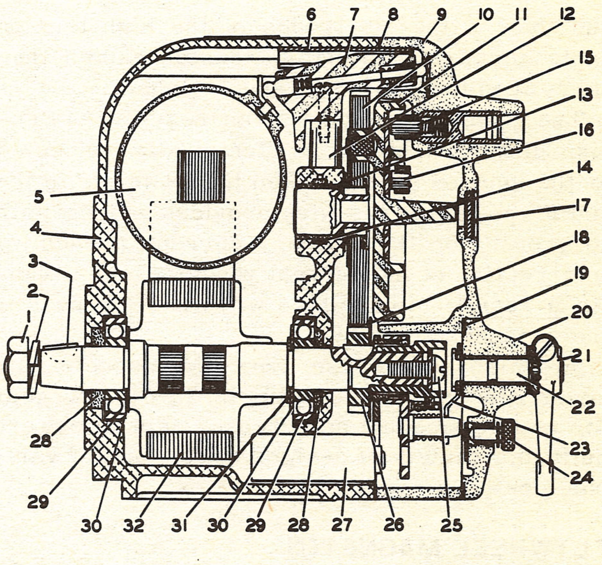
35-58. Schematic diagram of rotating magnet magneto.

The current induced in the primary winding produces a magnetic field which surrounds the secondary winding. This field reaches its maximum when the current in the primary winding reaches its maximum. At the instant of maximum current in the primary winding, the breaker points are caused to open by the action of the breaker cam. This stops the flow of current in the primary circuit and causes the collapse of the magnetic field. The collapsing lines of force then induce a current in the secondary circuit and, as the ratio of turns in the secondary is high compared to those in the primary, a high tension voltage is produced.

The self-induced voltage produced in the primary winding, resulting from the collapsing magnetic field, is absorbed by the condenser which is shunted across the breaker points. In effect this action promotes a more rapid collapse of the primary field and at the same time reduces arcing at the breaker points.

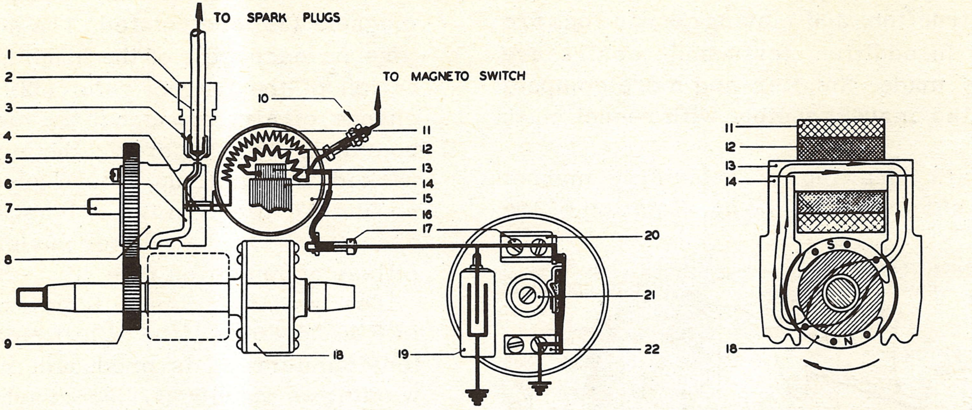
An example of the rotating magnet magneto is American Bosch type MJB magneto, Fig. 35-59. In this magneto the coil windings (5), condenser (27), and interrupter are stationary, while the magnets (32) are rotated. The screened ventilators on each side of the housing (4) and the fan action of the magnet rotor (32) insure constant change of air throughout the magneto. The ball bearings (20) supporting the magnet shaft are packed in high temperature grease and require no further attention for at least a year of normal operation. The distributor bushing (14) is of the oilless composition type.

The type PA4, Bendix Scintilla magnet, shown in Fig. 35-60, is of the rotating magnet type. High tension current is produced in the secondary winding as previously described. One end of the primary winding (12) is grounded to the magneto housing, while the other end is connected to the insulated contact point. When the contact points (20) are closed, the primary circuit is completed, permitting current to flow in the primary winding. One end of the secondary winding (11) is connected to the insulated end of the primary winding, while the other end terminates at the



35-59. American Bosch type MJB rotating magnet magneto. (1) Nut drive shaft. (2) Lockwasher. (3) Key. (4) Magneto housing. (5) Coil. (6) High tension conductor insulation. (7) High tension conductor. (8) Distributor plate gasket. (9) Distributor plate. (10) Distributor gear. (11) Distributor rotor. (12) Distributor gear bracket. (13) Distributor gear shaft bearing. (14) Bearing wick. (15) Distributor plate brush. (16) Distributor plate brush. (17) Observation window. (18) Indicating disk. (19) End cap gasket. (20) End cap. (21) Timing lever. (22) Timing lever shaft. (23) Timing lever bracket. (24) Short circuit screw. (25) Cam fastening screw. (26) Magnet rotor gear. (27) Condenser. (28) Felt washers. (29) Ball bearing. (30) Grease retaining washers. (31) Equalizing washer. (32) Magnet rotor.

high tension insert in the coil. High tension current in the secondary winding is conducted to the center of the distributor cylinder (6) by means of the carbon brush (4). From there it is conducted to the segments of the distributor cylinder and then to the electrodes of the high tension cable terminals (1). High tension cables then carry it to the individual spark plugs.



1 HIGH TENSION TERMINAL
2 HIGH TENSION CABLE
3 CABLE CLIP
4 CARBON BRUSH
5 DISTRIBUTOR GEAR - LARGE
6 SEGMENT IN DISTRIBUTOR CYLINDER
7 DISTRIBUTOR AXLE
8 DISTRIBUTOR CYLINDER
9 DISTRIBUTOR GEAR - SMALL
10 GROUND TERMINAL
11 SECONDARY WINDING
12 PRIMARY WINDING
13 COIL CORE
14 POLE SHOE EXTENSION
15 MAGNETO COIL
16 PRIMARY CONNECTOR
17 SCREW - FASTENING - ADJ. CONTACT ASSEMBLY
18 ROTATING MAGNET
19 CONDENSER
20 ADJUSTABLE CONTACT ASSEMBLY
21 BREAKER CAM
22 CONTACT AND CAM FOLLOWER ASSEMBLY

35-60. Details of Bendix type PA4, rotating magnet magneto, showing electric and magnetic circuits.

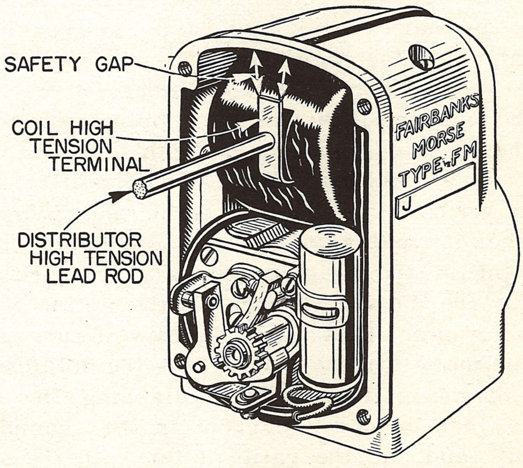
The ground terminal (10) on the type PA4 Bendix Scintilla magneto is electrically connected to the ignition switch. When the switch is in the "OFF" position, this wire provides a direct path to ground for the primary current, preventing interruption of the current when the points open. As a result, high voltage will not be induced in the secondary circuit.

A Fairbanks Morse type FM magneto with cover removed is shown in Fig. 35-61. Note gear for rotating magnet and breaker cam. These are built in a variety of designs for engines of various sizes and compression ratios.

FLYWHEEL MAGNETOS

Flywheel magnetos, Fig. 35-62, are of the revolving magnet type and are used extensively for ignition on small internal combustion engines used on lawn mowers, garden tractors, outboard motors, etc. For the most part, flywheel magnetos are used on single cylinder engines, but are also used occasionally on two and four cylinder engines.

The theory of operation is similar to that of the rotary magneto. In the typical flywheel magneto the magnet is mounted on the outer rim of the flywheel which revolves around the stationary ignition coil, condenser and breaker point assembly. As the ends of the magnet pass by the pole pieces, an alternating magnetic flux is established through the ignition coil and current is generated in the primary circuit during the period that the breaker points are closed. A cam located on the crankshaft opens the points when the primary current is at a maximum. Interruption of the current causes the magnetic field to collapse, which in turn induces a high tension voltage in the secondary winding.



35-61. Fairbanks Morse type FM, rotating magnet magneto.

A WICO flywheel magneto for single cylinder engines is shown in Fig. 35-63. A type K1-503

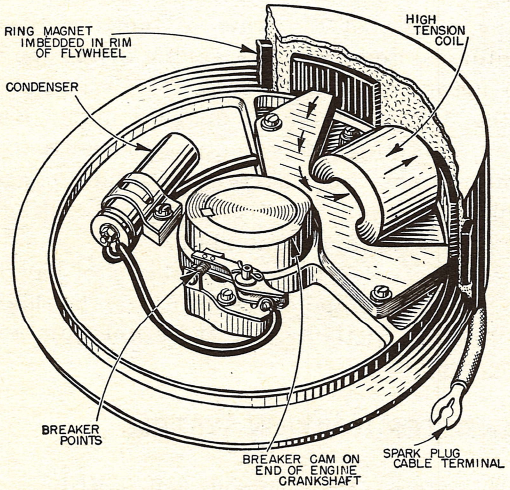
Bendix Scintilla magnet, also for use on single cylinder engines, is shown in Fig. 35-64, and Fig. 35-65 gives the details of a flywheel type magneto for two cylinder engines. This is also of Bendix Scintilla manufacture. Note that it consists basically of two complete ignition systems with individual coils, breaker points and condensers.

MAGNETO SPARK ADVANCE

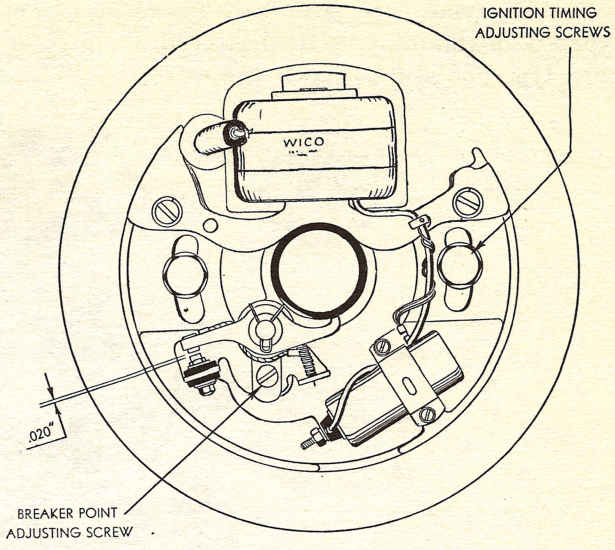
In order to advance the timing of the spark in accordance with different engine speeds and loads, both manual and automatic spark advance are used on magnetos. However, the manual advance is virtually obsolete.

As the magneto produces an ignition spark at the instant the breaker points open, the spark timing can be advanced or retarded through a limited range by shifting the point at which the breaker points open. This is accomplished by rotating the plate on which the breaker points are mounted through an arc of approximately 10 deg. However, the amount of advance or retard that can be obtained by such a method is definitely limited, as the intensity of the ignition spark decreases rapidly as the points are opened farther away from the point of maximum current.

Automatic spark advance on magnetos is obtained by means of a centrifugally controlled spark advance rotor, Fig. 35-66. This depends for its action on two spring loaded pawls which are held close to the center of the rotor at low speeds and gradually swing outward as engine speed increases. Outward movement of the pawls is transferred by linkage to the breaker camshaft with the result that the cam changes its relative position in respect to the drive shaft. In that way the spark timing is advanced. The degree and rate of spark advance is controlled by a pawl stop and the strength of the springs holding the centrifugal weights.


RING MAGNET IMBEDDED IN RIM OF FLYWHEEL
HIGH TENSION COIL
CONDENSER
BREAKER POINTS
BREAKER CAM ON END OF ENGINE CRANKSHAFT
SPARK PLUG CABLE TERMINAL

35-62. *Flywheel type magneto.*


IGNITION TIMING ADJUSTING SCREWS
WICO
.020"
BREAKER POINT ADJUSTING SCREW

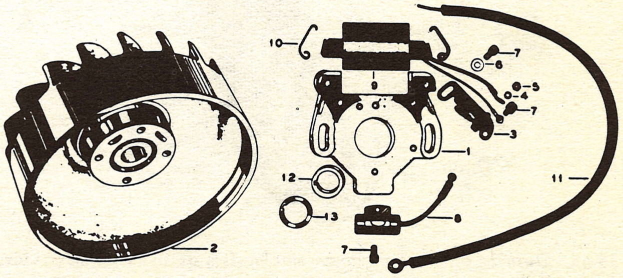
35-63. *WICO magneto as used on Gladden series 40 engines.*

It should be pointed out that in general, magnetos are used on engines which are operated through a relatively small range of speeds and therefore do not require as wide a range of spark timing as is used on current passenger car engines.

IMPULSE COUPLINGS

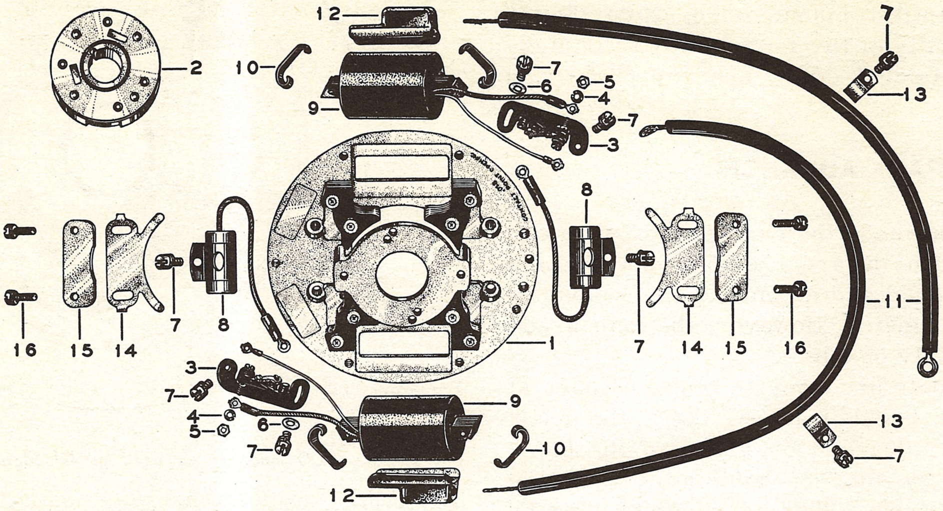
In order to intensity the spark while the engine is being cranked, magnetos on certain installations are provided with an impulse coupling. In addition, the impulse coupling automatically retards the spark during the starting period in order to prevent engine back firing.

There are many different types of impulse couplings. However, the basic principles of the



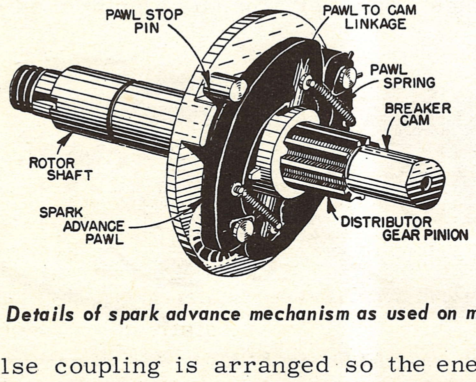
35-64. *Bendix-Scintilla type KI-503 flywheel magneto for use on single cylinder engines. (1) Magneto mounting flange. (2) Flywheel and magnet assembly. (3) Breaker point assembly. (4) Lock washer. (5) Nut. (6) Washer. (7) Screw and lock washer. (8) Condenser. (9) Ignition coil. (10) Coil clamp. (11) High tension lead. (12) Breaker cam. (13) Washer.*

different types are similar. These different types of design may be listed as follows: pivoted pawl type and sliding pawl type.



35-65. *Bendix-Scintilla type K2A-1 flywheel magneto for two cylinder engines. (1) Magneto mounting flange.(2) Rotating magnet. (3) Breaker point assembly. (4) Lock washer. (5) Nut. (6) Washer. (7) Screw and lock washer. (8) Condenser. (9) Ignition coil. (10) Coil core clamp. (11) High tension lead. (12) High tension insulator. (13) Clamp. (14) Magneto flange tension spring. (15) Flange tension spring plate. (16) Screw and lock washer.*

The pivoted pawl type which is shown in Fig. 35-67 has each pawl securely fastened to the hub plate, its movement being confined to a turning action in an arc about its pivot point. In the sliding pawl design, Fig. 35-68, the pawls are free, but move in a guide which restricts their movement to a straight line. Basically the impulse coupling acts as a mechanical reservoir to store the energy which is available at a low rate during the engine cranking period. This accumulated energy is then released to the magneto at the instant that the spark is required to ignite the charge in the cylinder. The impulse coupling is arranged so the energy is released to provide a retarded spark during the starting period.



35-66. *Details of spark advance mechanism as used on magnetos.*

A shell and hub connected together with a strong spring form the basic parts of the impulse coupling. The shell is fitted to the engine drive shaft, while the hub is rotated by the magneto shaft. At cranking speeds, a pawl on the hub engages a pin mounted on the magneto frame preventing further movement of the magneto rotor, while the engine half of the coupling continues to rotate. This relative change in position winds up the connecting spring. Then, at the time of ignition, the pawl is released and the drive spring snaps the magneto rotor forward through its firing position. As the engine starts to operate under its own power, centrifugal force acts on the pawls to draw them into position where they do not engage the coupling stop pin, and the impulse coupling then acts as a solid drive member.

By selecting different numbers of pawls and stop pins, the impulse coupling can be designed to operate engines with different numbers of cylinders.

TRANSISTOR IGNITION SYSTEM

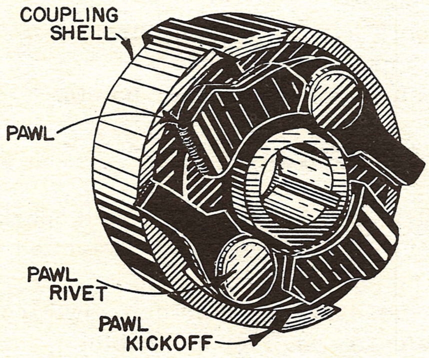
The output of a conventional ignition system is limited by the amount of current in the primary circuit, and this in turn, is limited by the amount of current that can be interrupted by the conventional tungsten contact points. This is approximately 5 amp. for reasonable contact life. Another factor limiting the output is the period the contact points remain closed and as the engine speed increases, this time becomes increasingly short.

To overcome these problems, Electric Auto-

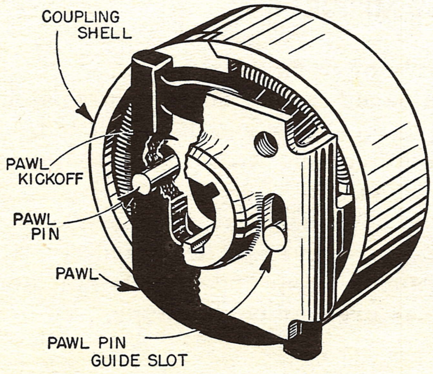
Lite developed the transistor ignition system.

The transistor is a solid metallic device with the ability to switch large currents through the action of a very small control or relay current. The switching action of the transistor involves no moving parts and can be made instantaneous through proper circuit design. The use of a conventional contact set serves to turn the transistor "off" and "on" at the proper time in relation to engine timing. Furthermore, the current switched by the transistor can be greatly increased over the current normally controlled by ignition breaker points; and at the same time, the control current can be reduced to such a low value that the life of the controlling contacts is greatly extended over that in conventional systems.

The Auto-Lite transistor switched transformer is a single package containing a specially designed high voltage transformer, the transistor, its heat sink and the necessary circuitry. A resistor is supplied for external mounting in the primary circuit. The package is designed to replace the conventional ignition coil. The regular distributor is used, but without the condenser. A diagram of the system is shown in Fig. 35-69.

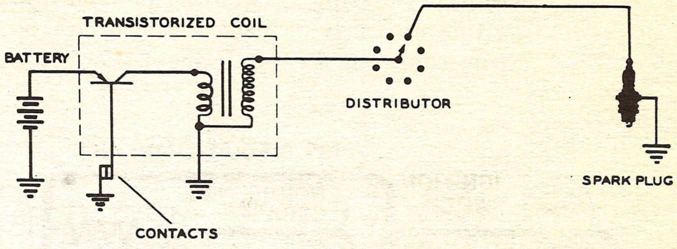


35-67. *Pivoted pawl type of impulse coupling.*



35-68. *Sliding pawl type impulse coupling.*

It is claimed that there is no dropoff or loss of ignition at high engine speeds, and the constant voltage output gives the system performance characteristics equal to battery ignition at low speeds, and a magneto system at high speeds. Contact life, because of the low current handled, is said to be unlimited.



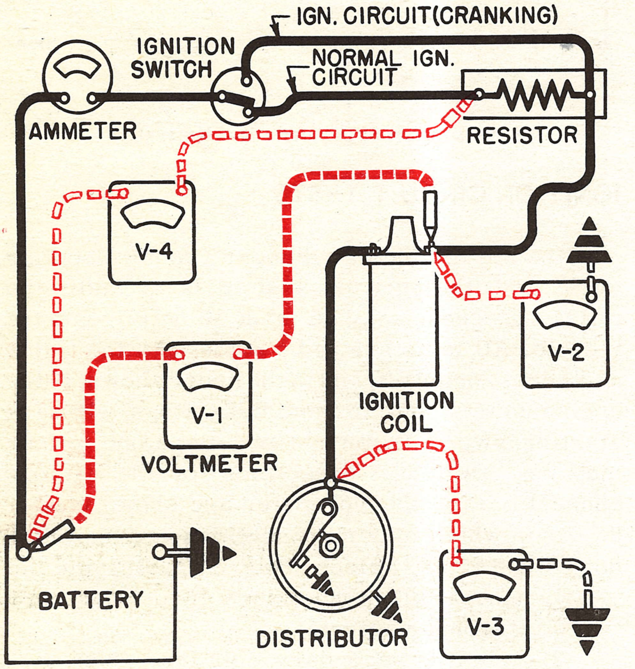
35-69. *Diagram of transistor ignition system.*

IGNITION CIRCUIT TESTS

If the checks indicated under Trouble Shooting show that the ignition system is at fault, the following checks may be made to help locate the trouble. All tests are to be made with the lights and accessories off, and in the order shown. If the engine starts, but immediately stops when the starting switch is turned off, steps one to four may be omitted. Connections for the various connections of the voltmeter are shown in Fig. 35-70 in which meter connections are shown by dotted red lines. Values apply to 12 volt systems.

1. Check all connections in primary and secondary circuit.
2. Remove secondary coil lead from distributor cap. Hold 1/4 in. from engine while cranking and observe if spark occurs. If spark occurs, check distributor cap, rotor and spark plug wiring.
3. Connect voltmeter as shown at V-1, Fig. 35-70. Reading should be 1 v. maximum, while cranking engine. If no reading is obtained, trouble may be: open ignition circuit used during cranking. Ignition switch not closing ignition circuit during cranking. Ground in circuit from coil terminal to ignition switch. Ground in coil.
4. Connect voltmeter as shown at V-2. Ignition switch on, breaker points open. Meter should show normal battery voltage. If not, trouble may be: Low battery. Breaker points not open. Ground in circuit from coil to distributor. Ground in distributor. Ground in coil. Ground in ignition circuit used during cranking or in lead connecting coil to resistor.
5. Connect voltmeter as shown at V-2, ignition switch on, points closed. Meter

reading should be 5 to 7 v. If higher than 7 v.: Contacts may not be closed. A loose connection in distributor. Distributor not grounded to engine. Faulty breaker points. Loose connection between distributor coil and distributor. Resistor out of circuit due to shorted or incorrect wiring. Starting contacts of ignition switch may stay closed. Resistor has too little resistance. Resistance should be within specified value. If meter reading is less than 5 v., trouble may be: Loose connection from resistor through ignition switch to battery. Loose connection between resistor and coil. Resistance is open or has too much resistance.



35-70. Connections for checking voltage drop in ignition circuit.

6. Connect voltmeter as shown as V-3, ignition switch on and points closed. Meter reading should be 0.2 maximum. If not: Contacts are not closed. Loose connection in distributor. Distributor not grounded to engine. Defective breaker points. The voltage drop across the ignition breaker points should not exceed 0.125 v.
7. Connect voltmeter as shown as V-4. Ignition switch on and points closed. Meter reading should not exceed 0.7 v. If not check for loose connection from resistor through ignition switch circuit to battery.
8. If these checks fail to find the cause of the trouble, remove coil, distributor and resistor and check separately. Also check wiring harness.

IGNITION TROUBLE SHOOTING

ENGINE WILL NOT START

(Also see starting and fuel system troubles)

Weak battery.

Excessive moisture on high tension wiring and spark plugs.

Cracked distributor cap.

Faulty coil.

Faulty condenser.

Coil to distributor high tension lead not in place.

Loose connections or broken wire in low tension circuit.

Faulty ignition breaker points.

HARD STARTING

Faulty or improperly gapped spark plugs.

Faulty or improperly adjusted breaker points.

Loose connections in primary circuit.

Defective high tension cables.

Low capacity condenser.

Faulty distributor cap or rotor.

ENGINE MISFIRES

Dirty or worn spark plugs.

Damaged insulation on high tension wires.

High tension wires disconnected.

High tension wires incorrectly routed to plugs.

Defective distributor cap.

Poor cylinder compression.

Breaker points incorrectly adjusted.

Weak breaker point spring.

QUIZ - ENGINE IGNITION

1-List the various units found in the modern ignition system.

2-What is the purpose of the ignition coil?

3-What is the voltage at the secondary of the ignition coil?
a. 5,000 volts
b. 12 volts
c. 110 volts
d. 20,000 volts
e. 100,00 volts

4-In addition to opening and closing the primary ignition circuit, what else does an ignition distributor do?

5-What is the purpose of the ignition condenser?

6-What is the purpose of the spark plug?

7-Describe briefly the construction of an ignition coil.

8-With the closing of the ignition switch, describe what happens in an ignition system.

9-Which is higher, ignition voltage at:
a. High speeds
b. Low speeds
c. The same at all speeds

10-When an arc is produced at the ignition breaker points, is the voltage induced in the secondary higher or lower than without an arc?
a. Higher
b. Lower
c. The same

11-Which requires the greater voltage to jump the gap, an old worn plug, or a new plug?
a. New plug
b. Old plug
c. Same in either case

12-What advantage is there in installing the ignition coil close to the distributor?

13-Is there any advantage in keeping the high tension leads as short as possible?

14-What advantage is there in having the high tension outlet of the ignition coil negative?

15-Describe the lead pencil test for determining the polarity of the ignition system.

16-Describe briefly the construction of an ignition condenser.

17-The capacity of an ignition condenser is measured in what units?
a. Volts
b. Farads
c. Joules
d. Microfarads
e. Ampere turns

18-If metal is transferred to the positive point of ignition breaker points, is the condenser too large or too small?
a. Too small
b. Too large

19-On what type of engine is a vibrator type ignition coil used, and for what purpose?

20-On a four-cycle engine at what speed is the distributor driven?
a. Engine speed
b. Half engine speed
c. Twice engine speed

21-On a two-cycle engine, at what speed is the distributor driven?
a. Engine speed
b. Half engine speed
c. Twice engine speed

22-On a typical distributor, how many lobes are there on the breaker cam for a six cylinder engine?
a. Three
b. Six
c. Twelve

23-The rotor in a distributor distributes the current to the various spark plugs. From where does it receive the current?

24-What engine conditions will affect the time that ignition should occur?

25-When the engine is idling, when is the spark usually timed to occur?
a. Before top center
b. After top center
c. Before bottom center

26-At higher engine speeds, why is it necessary to have the spark occur earlier?

27-At what point in the intake system is the vacuum advance connected?
a. Atmospheric side of the carburetor throttle
b. Engine side of the carburetor throttle
c. Vacuum side of the fuel pump

28-As load on an engine is increased, is more or less spark advance required?
a. More spark advance
b. Less spark advance

29-What is cam angle?

30-When cam angle is small, will there be more or less time for current to pass through the primary circuit?
a. More time
b. Less time

31-In the Ford Loadomatic distributor, how is the spark advance controlled?
a. By centrifugal force only
b. By vacuum only

c. By a combination of vacuum and centrifugal force

32-What points can be checked with a modern distributor testing equipment?

33-When aligning breaker points, which part of the assembly should be bent?
a. The stationary point
b. The movable point

34-Why is a resistor used in the primary ignition circuit?

35-There are two general types of resistors used in the primary ignition circuit. One is a single unit or block type and is mounted on the firewall of the engine. What is the other type?

36-What is the approximate resistance of the resistors used in the primary circuit?
a. 18 ohms
b. 25 ohms
c. 1.5 ohms
d. 15 ohms

37-List two places where timing marks are placed on an engine.

38-In the dual advance distributor used on some Ford engines how is the vacuum advance controlled?

39-Give the firing order of an in-line six cylinder engine?

40-Give a firing order of a V-8 engine.

41-What is meant by the heat range of spark plugs?

42-At high speeds what is the approximate temperature of the center wire of a spark plug?
a. 212 deg.
b. 400 deg.
c. 800 deg.
d. 3,200 deg.

43-Which plug is termed the hotter: a plug with a long path for the heat to travel, or a plug with a short path?
a. Long path b. Short path

44-What three types of fouling are spark plugs subject to?

45-An ignition system that is capable of delivering 20,000 volts to a clean spark plug, may be able to deliver only half that amount to a fouled plug. Why?

46-Why are wider spark plug gaps favored over narrow gaps?

47-Give two reasons why the surface of the cylinder head against which the spark plug seats must be clean.

48-What are some advantages of magneto ignition?

49-What method is used to produce the magnetic field in a magneto?

50-When reconditioning a spark plug, what should be done to the center electrode?

51-Give two classifications of magnetos.

52-In the inductor-type magneto where are the coil and magnet mounted?
a. Both in stationary positions
b. The magnet rotates and the coil is stationary

53-In a rotating magnet magneto, which of the following parts rotate and which are stationary? Coil. Condenser. Breaker points.

54-Describe the operation of a flywheel-type magneto.

55-What is the purpose of an impulse coupling?

56-In a transistor-type ignition system, what does the transistor do?
a. Transforms the battery voltage to high voltage
b. "Switches" on and off the primary current
c. Distributes the high tension current

57-Give five causes originating in the ignition system, why an engine will not start.

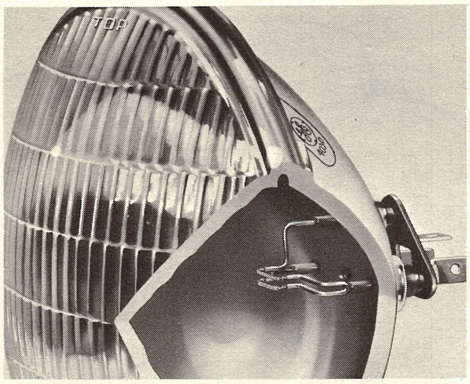
58-Give five causes originating in the ignition system why an engine will be hard to start.

59-Give five causes originating in the ignition system why an engine misfires.

LIGHTS, LIGHTING CIRCUITS, HORNS, BATTERIES

Many modern cars have in excess of 20 different lights ranging from the small indicator lamp drawing approximately .25 amp., to the large sealed beam head lamp drawing in excess of 8 amp. for six volt units to over 4 amp. for the twelve volt type.

A typical sealed beam head lamp is shown in Fig. 36-1. In these lamps the filament, reflector and lens form a single unit. As the unit is completely sealed, the reflector never becomes tarnished, and as a result, the light output is not seriously affected by age. The filament is correctly focused in relation to the reflector and the lens at the time of manufacture, and consequently there is no need to focus these lamps. However, it is necessary to aim them correctly, to provide maximum illumination on the road, and at the same time avoid blinding approaching drivers.

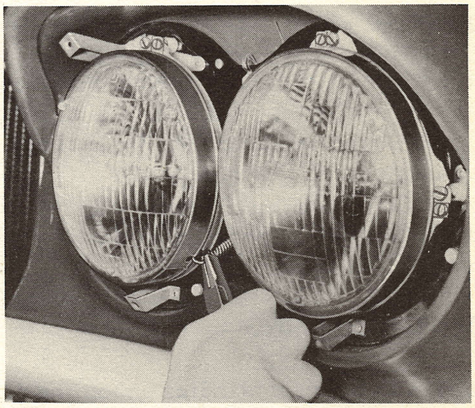


36-1. Cut-away view of modern sealed beam headlight.

REMOVING SEALED BEAM UNITS

Removal of the sealed beam unit from the car is simple. The procedure is to first remove the head lamp door screws, permitting removal of the door. Unhook the spring from the retainer ring, Fig. 36-2. Then, remove screws indicated in Fig. 36-3. These screws hold the retaining ring, and should not be confused with the adjusting screws which are adjacent and which are shown in Fig. 36-6. The aiming screws should not be turned unless it is necessary to aim the lights. After removing the retainer ring and sealed beam unit, Fig. 36-4, the lamp is separated from the wire connector, Fig. 36-5.

In most cases the screws for vertical aiming are at the top of the unit, and the horizontal aiming screws are at the side, Fig. 36-6. However, in some instances where dual headlights are used, the vertical adjustment is placed at the bottom.

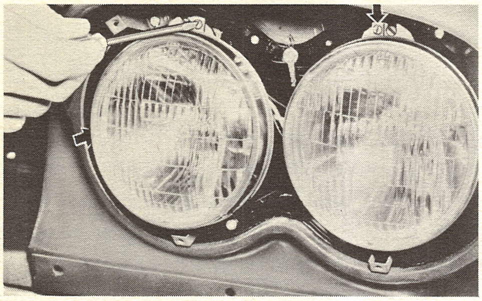


36-2. Unhooking spring from retainer ring of sealed beam headlamp.

Fig. 36-6 shows a number "1" embossed in one lamp and a number "2" in the other. These are to identify the lamps, the number "2" being for outboard mounting and number "1" for inboard mounting. The outboard lamps have two filaments and a three-blade terminal, while the number "1" lamp has only a single filament and a two-blade terminal. The latter provides the high intensity reach down the highway, and the off focus of No. 2 lamp, illuminates the side of the road.

AIMING THE HEADLIGHTS

By means of the three guide points formed into the front of the lens of the sealed beam units, and indicated in Fig. 36-5, aiming of the headlights is greatly simplified. Special equipment, such as shown in Fig. 36-7 is used. Other types are also available. Such equipment has the advantage that aiming is completed without turning on the lights. The equipment is provided with an accurate level so it is not necessary to have the vehicle on a level floor.



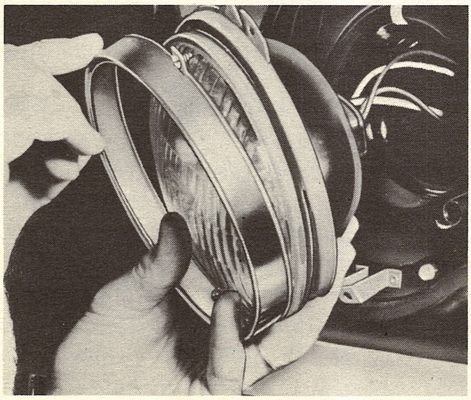
36-3. Removing screws securing retaining ring.

Headlights can also be aimed by means of a screen as shown in Fig. 36-8. When using such a screen the floor must be level, and the shop cannot be brightly lighted. In addition, tires must be correctly inflated.

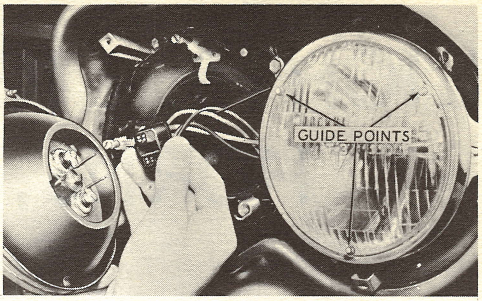
When focusing a sealed beam headlight, the adjustment at the top of the retaining ring, Fig. 36-6, will raise or lower the light beam, while the adjustment at the side will swing the beam to the right or the left. These adjustments are reached after the outer decorative ring has been removed.

HEADLAMP DIMMING

In order to prevent blinding oncoming drivers, headlamps are provided with two beams and a switch so it is possible to switch from a low beam to a high beam as driving conditions require. A typical circuit of a foot-controlled dimmer switch is shown in Fig. 36-9.

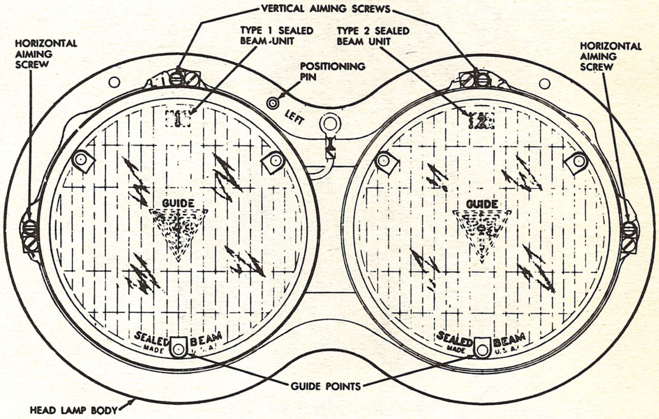


36-4. Removing sealed beam lamp and retaining ring.



36-5. Disconnecting sealed beam unit.

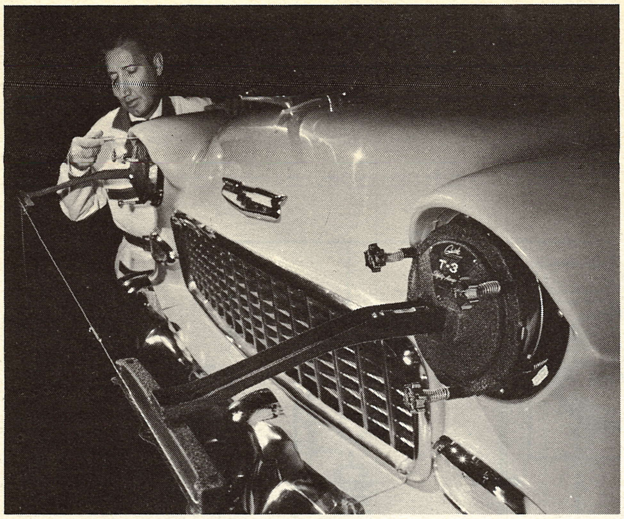
Depression of the control button turns the rotary contacts one position within the switch. The button is spring loaded, and when released automatically returns to the reset position to be ready for the next cycle. The switch is constructed so the contacts overlap; that is, the new circuit is made before the old one is broken. In that way, there is no period without illumination while switching from one beam to the other.



36-6. Dual headlamp installation. (left) Note aiming screws and guide points for aiming.

LIGHTING CIRCUIT

The modern lighting circuit, Fig. 36-10, includes the battery, frame, all the lights and various switches that control their use. The lighting circuit is known as the single-wire system, (using the frame of the car for the return) as compared to the two-wire system, which was used on the more expensive cars during the formative period of the industry. The



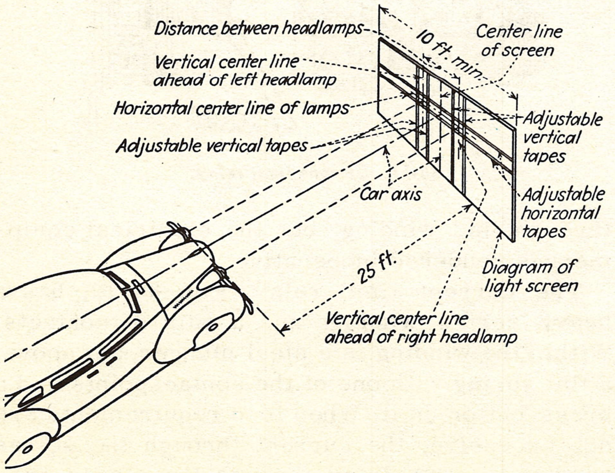
36-7. *Adjusting dual headlights with special tester.*

two-wire system was abandoned because of high cost.

The complete lighting circuit of the modern passenger car can be broken down into individual circuits each having one or more lights and switches. In each separate circuit, the lights are connected in parallel, and the controlling switch is in series between the group of lights and the battery. As an example, the parking lights are connected in parallel and controlled by a single switch. In some installations, one switch controls the connection to the battery while a selector switch determines which of two circuits is energized. The headlights with their upper and lower beams, are an example of such a circuit.

In some instances, such as the dome lights, several switches may be connected in parallel so that any switch may be used to turn on the light.

When studying the wiring diagram, all light circuits can be traced from the battery, through the ammeter to the switch (or switches) to the individual light.


Distance between headlamps
10 ft. min.
Center line of screen
Vertical center line ahead of left headlamp
Horizontal center line of lamps
Adjustable vertical tapes
Adjustable vertical tapes
Car axis
Adjustable horizontal tapes
25 ft.
Diagram of light screen
Vertical center line ahead of right headlamp

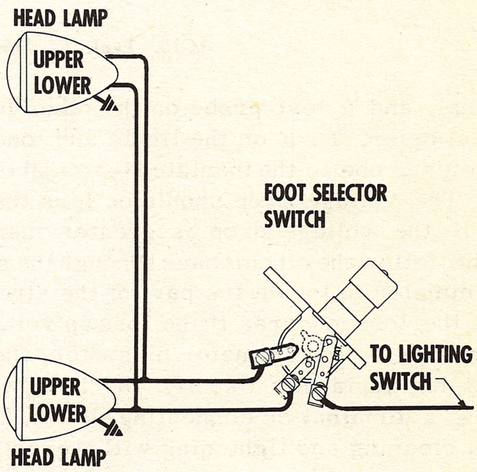
36-8. *Specifications of the Society of Automotive Engineers for headlight testing.*

HEADLAMP SERVICE KINKS

Short life or frequent burning out of head lamps results from excessive voltage. This in turn may result from loose or corroded electrical connections in the battery circuit or the generator charging rate may be set too high. The setting of the voltage regulator should also be checked.

Dim lights result from low voltage, and this in turn, may be caused by loose or corroded terminals in the lamp circuit. Or, the generator charging rate may be too low, the battery may be defective, or the voltage regulator may be set incorrectly.

The wiring in lighting circuits should be inspected periodically for loose and corroded connections, and chafed insulation. The connections at junction blocks and wire connections should be especially checked. Switches, bulb sockets, lamp shells, reflectors and lenses should also be inspected for loose mounting and corrosion.

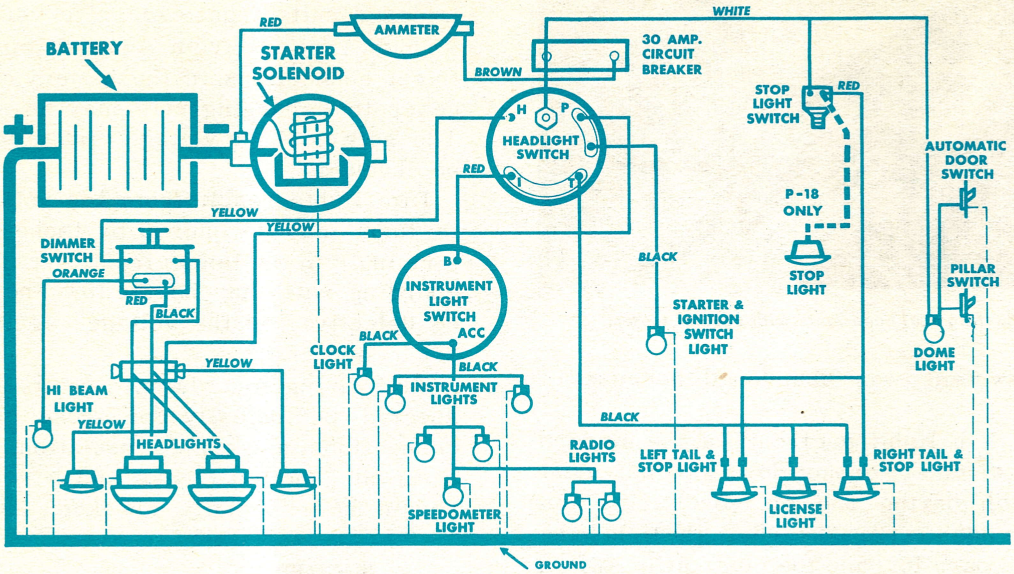

HEAD LAMP
UPPER
LOWER
FOOT SELECTOR SWITCH
TO LIGHTING SWITCH
UPPER
LOWER
HEAD LAMP

36-9. *Typical circuit of headlight dimmer circuit.*

In order to overcome the effects of rust on old cars, it is frequently necessary to solder a lead to a lamp socket case and ground the other end of the lead on the frame.

The voltage drop between the various lamp sockets (not the holder, reflector, or shell) and the ground, should be measured with a low-reading voltmeter. Each light should be turned on when making this test for high resistant ground connections. If any reading is obtained on the voltmeter, it is an indication that there is resistance present, and shell and socket must be carefully cleaned to obtain a good electrical connection.

Another test to be made is checking the voltage drop between the battery and each individual lamp. To make this test, connect a long voltmeter lead to the ungrounded starting battery terminal, and a test probe on the other lead of the voltmeter. Turn on the lights and touch the voltmeter probe to the insulated terminal of each lamp. The voltage drop should be less than 0.6 volt. If the voltage drop is greater than that amount, follow the circuit back through the switch and ammeter to locate the part of the circuit in which the loss occurs. If the loss in voltage is due to a defective ammeter or switch, the part should be replaced. Usually the loss will be found at a terminal or connecting sleeve. In such cases, cleaning and tightening will overcome the trouble.


BATTERY
+
−
RED
AMMETER
STARTER SOLENOID
BROWN
WHITE
30 AMP. CIRCUIT BREAKER
H
P
HEADLIGHT SWITCH
RED
STOP LIGHT SWITCH
RED
AUTOMATIC DOOR SWITCH
P-18 ONLY
YELLOW
YELLOW
DIMMER SWITCH
ORANGE
RED
BLACK
B
INSTRUMENT LIGHT SWITCH
ACC
BLACK
BLACK
STOP LIGHT
PILLAR SWITCH
STARTER & IGNITION SWITCH LIGHT
DOME LIGHT
CLOCK LIGHT
BLACK
INSTRUMENT LIGHTS
YELLOW
HI BEAM LIGHT
YELLOW
HEADLIGHTS
BLACK
RADIO LIGHTS
LEFT TAIL & STOP LIGHT
RIGHT TAIL & STOP LIGHT
LICENSE LIGHT
SPEEDOMETER LIGHT
GROUND

36-10. Typical lighting circuit. (Electric Auto-Lite on Plymouth)

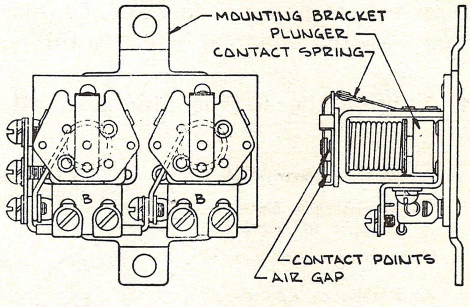
FUSES AND OVERLOAD RELAY

A fuse or overload relay, Fig. 36-11, is usually connected between the battery and the main lighting switch. The fuse or relay is usually mounted on the back of the ammeter, instrument panel or on the fire wall (dash).

When a short circuit or overload occurs in a circuit, the fuse burns out and opens the circuit, so that no further damage will result. The thermal overload relay operates by heating a strip or bimetal on which a contact is mounted. When a short circuit occurs, the excessive current heats the bimetal, causing it to bend and open the contacts. This opens the circuit, until the bimetal cools after which the contacts again close, completing the circuit. This cycle continues until the short is removed.

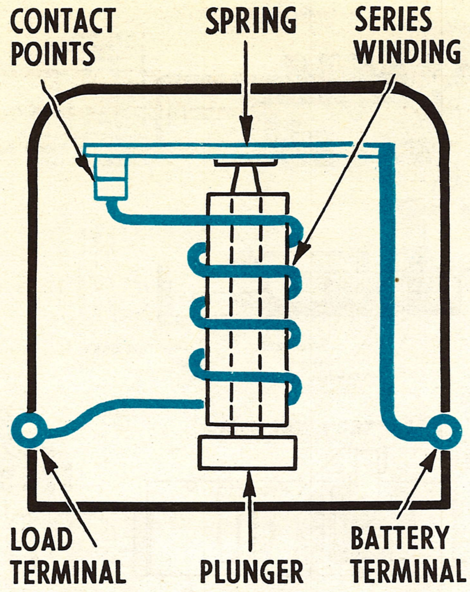
Another form of current limit relay uses a solenoid to control a set of contact points. There are two types, the vibrating and lockout type. On the vibrating type, excessive current will cause the relay to vibrate, and also cuts down the amount of current flowing so that excessive current cannot flow and cause damage.

In the lockout type, the contact points are held open by a separate winding connected between the points. A small current continues to flow through this winding, but the electrical equipment is rendered inoperative.


MOUNTING BRACKET
PLUNGER
CONTACT SPRING
B
B
CONTACT POINTS
AIR GAP

36-11. Current limit relay.

The current limit relay, Fig. 36-12, has a heavy series winding and a pair of contacts. Within the winding is a steel plunger, and above, a flat spring with one of the contact points and a brass button on it. When load requirements are not excessive, the current through the series winding is completed through the closed contact points. When there is a short circuit causing a high current, the magnetic field built by


CONTACT POINTS
SPRING
SERIES WINDING
LOAD TERMINAL
PLUNGER
BATTERY TERMINAL

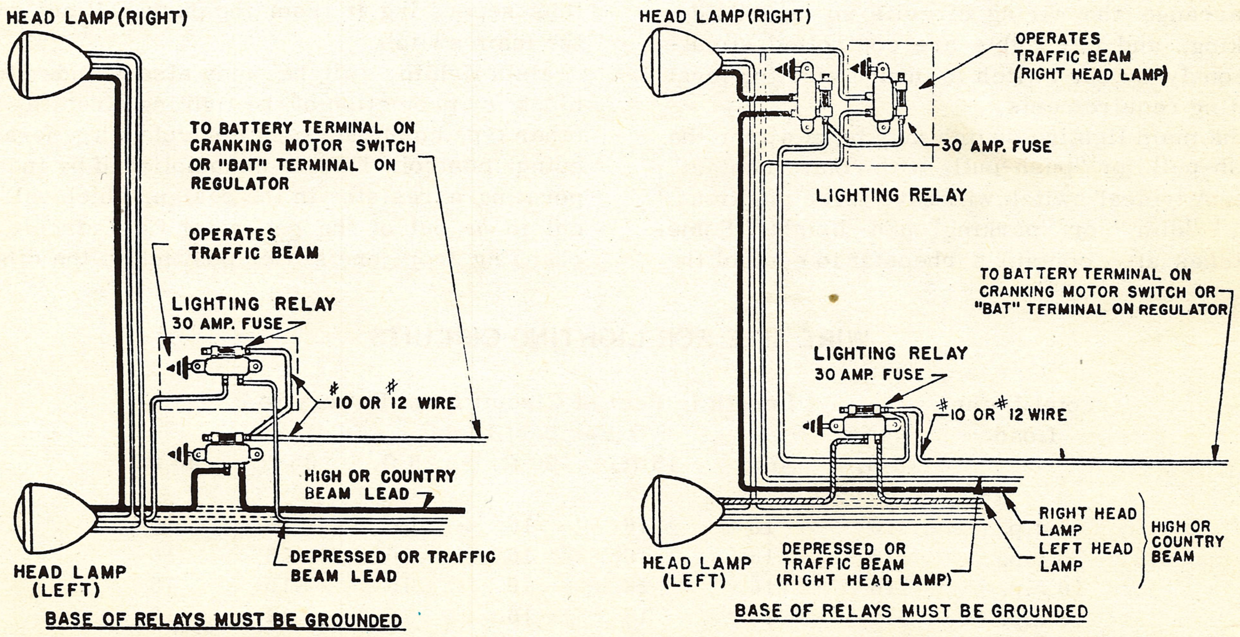
36-12. Wiring diagram of current limit relay. Note that contact points and relay winding are in series.

the series winding, is strong enough to move the plunger, which in turn strikes the brass button on the spring, forcing the contact points apart. As soon as the contacts open, current ceases to flow, and the plunger moves to its original position, permitting the contact points to close again. The resulting vibrating action keeps the current from becoming excessive. The lockout type current limit relay has an additional winding connected across the contact points which maintains the points in the open position, as long as the abnormal circuit condition exists.

LIGHT RELAYS

Because of the limited voltage available in automotive lighting circuits, it is necessary to keep the resistance of the connecting wires to a minimum. A big aid in this is the use of heavier gauge wire. However, the cost of such wire is high and, as a consequence, light relays are used to reduce the voltage loss. The relay can be placed in a position that decreases the length of the wiring, thereby reducing the voltage losses. The relay also eliminates the necessity of the main switch carrying all of the current and, therefore, eliminates the voltage loss due to burned switch contacts.

The wiring diagram for a typical lighting relay is shown in Fig. 36-13. Two lighting relays provide control of both high and low beams. When the lighting switch is placed in the high beam position, the winding of the lower relay is connected directly to the battery. The contacts of the lower relay will then close so the circuit from the battery to the high beam filaments is completed. When the selector switch is operated to obtain the depressed beam, the winding of the upper relay is connected to the battery, closing the relay points to connect the low beam filaments to the


HEAD LAMP (RIGHT)
TO BATTERY TERMINAL ON CRANKING MOTOR SWITCH OR "BAT" TERMINAL ON REGULATOR
OPERATES TRAFFIC BEAM
LIGHTING RELAY
30 AMP. FUSE
#10 OR #12 WIRE
HIGH OR COUNTRY BEAM LEAD
HEAD LAMP (LEFT)
DEPRESSED OR TRAFFIC BEAM LEAD
BASE OF RELAYS MUST BE GROUNDED
HEAD LAMP (RIGHT)
OPERATES TRAFFIC BEAM (RIGHT HEAD LAMP)
30 AMP. FUSE
LIGHTING RELAY
TO BATTERY TERMINAL ON CRANKING MOTOR SWITCH OR "BAT" TERMINAL ON REGULATOR
LIGHTING RELAY
30 AMP. FUSE
#10 OR #12 WIRE
RIGHT HEAD LAMP
LEFT HEAD LAMP
HIGH OR COUNTRY BEAM
HEAD LAMP (LEFT)
DEPRESSED OR TRAFFIC BEAM (RIGHT HEAD LAMP)
BASE OF RELAYS MUST BE GROUNDED

TWO BEAM LIGHTING SYSTEM WITH RELAYS IN COUNTRY AND TRAFFIC BEAM CIRCUITS

MULTIPLE BEAM LIGHTING SYSTEM WITH A RELAY IN EACH BEAM CIRCUIT OF RIGHT HEAD LAMP AND HIGH OR COUNTRY BEAM CIRCUIT OF LEFT HEAD LAMP

36-13. Lighting relay circuits.

battery. At the same time, the winding of the lower relay is disconnected from the battery.

LIGHTING WIRE SIZES

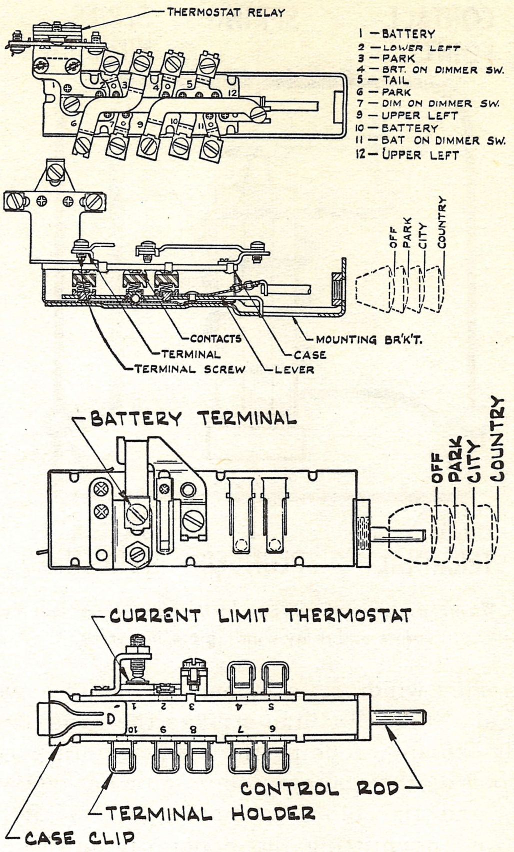
In order to conserve current, lighting wire must be of adequate size. The voltage loss in a length of wire is equal to the product of the current flowing and the resistance of the wire. Voltage loss or drop is also known as the IR drop. Keeping the resistance of the wire to a minimum will, therefore, keep the IR drop to a minimum. As the resistance of a length of wire decreases as its diameter increases, it is advisable to use wire of relatively large cross section. In general, nothing smaller than No. 16 gauge wire should be used for lights of small candle power; for headlights and other lights of high candle power, wire of still larger gauge is required.

LIGHTING SWITCHES

Originally, individual switches are provided for each light. On modern cars, a single switch unit is provided, Fig. 36-14, with individual switches being provided for special purpose lights such as dome lights, fog lights, etc. The modern switch provides control of such lights as head, fender, tail, side and instrument panel in a single unit.

In most vehicle installations, it is customary to arrange the wiring circuits so head, side, parking, and tail lights are controlled simultaneously by one switch to insure meeting legal lighting requirements.

The main lighting switch may be of either the "push-pull" or "push-pull with rotary contact" type. A typical switch will have three positions: "off," "dim," or "parking" and "bright." Some switches also contain a rheostat to control the brightness of the instrument panel lights. The rheostat is operated by rotating the control knob, thus separating it from the push-pull action of the main switch.


THERMOSTAT RELAY
1 — BATTERY
2 — LOWER LEFT
3 — PARK
4 — BRT. ON DIMMER SW.
5 — TAIL
6 — PARK
7 — DIM ON DIMMER SW.
9 — UPPER LEFT
10 — BATTERY
11 — BAT ON DIMMER SW.
12 — UPPER LEFT
OFF
PARK
CITY
COUNTRY
CONTACTS
TERMINAL
TERMINAL SCREW
MOUNTING BR'K'T.
CASE
LEVER
BATTERY TERMINAL
OFF
PARK
CITY
COUNTRY
CURRENT LIMIT THERMOSTAT
CONTROL ROD
TERMINAL HOLDER
CASE CLIP

36-14. Two types of lighting switches.

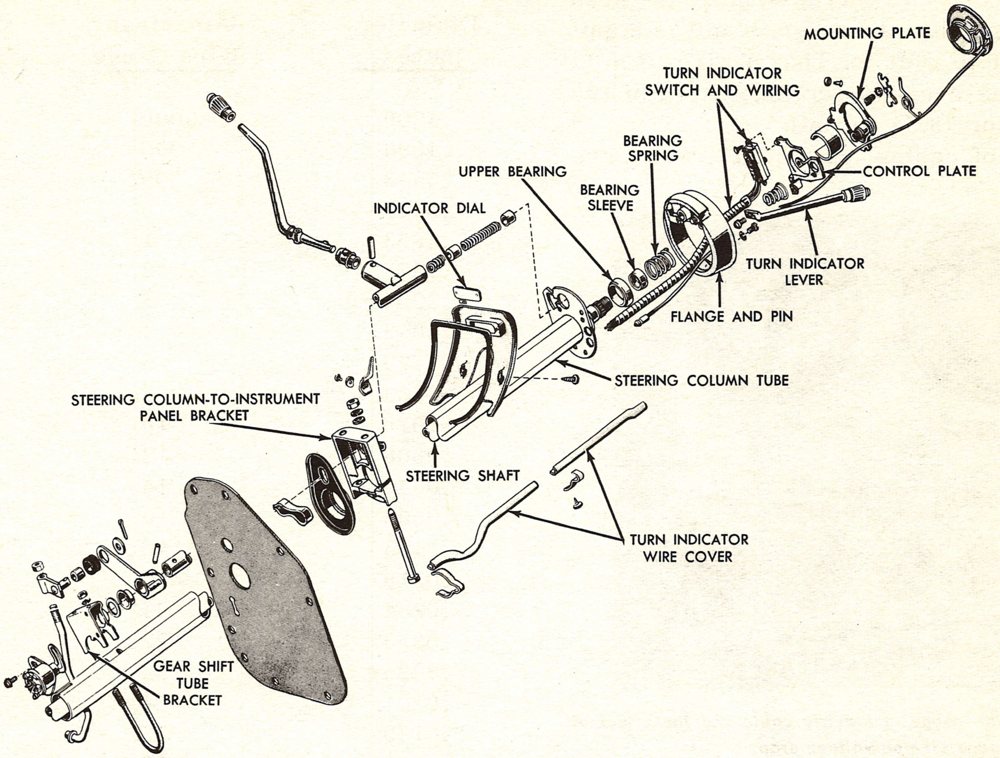
Main lighting switches may also include a fuse block for protection of the lighting circuits. Another type combines light control with generator output control. This is accomplished by incorporating a resistor in the design, which will be cut in or out of the generator field circuit, by changing from one switch position to the other.

WIRE SIZE FOR LIGHTING CIRCUITS

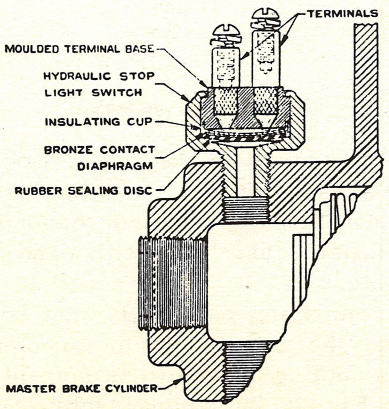
Total Lamp Load	Length in Feet of Circuit from Battery to Farthest Light						
	5 ft.	10 ft.	15 ft.	20 ft.	25 ft.	35 ft.	50 ft.
3 c.p.	16	16	16	16	16	16	16
5 c.p.	16	16	16	16	16	16	16
10 c.p.	16	16	16	16	16	15	13
15 c.p.	16	16	16	16	15	14	12
20 c.p.	16	16	16	15	14	13	11
25 c.p.	16	16	15	14	13	12	10
50 c.p.	16	14	12	11	10	9	7
75 c.p.	14	12	10	9	8	7	5
100 c.p.	13	11	9	8	7	6	4

DIRECTION SIGNAL SWITCHES

The direction signal switch, Fig. 36-15, is installed just below the hub of the steering wheel. A manually controlled lever projecting from the switch, permits the driver to signal or indicate the direction of the turn he is about to make. Moving the switch handle down will light the light bulbs on the left front and the left rear of the car, signaling a left turn. Moving the switch upward will light the lights on the right (front and rear), signaling a right turn. With the switch in a position to indicate a turn, the lights are alternately turned off and on by an interrupter or flasher included in the circuit.


MOUNTING PLATE
TURN INDICATOR SWITCH AND WIRING
BEARING SPRING
UPPER BEARING
BEARING SLEEVE
CONTROL PLATE
INDICATOR DIAL
TURN INDICATOR LEVER
FLANGE AND PIN
STEERING COLUMN TUBE
STEERING COLUMN-TO-INSTRUMENT PANEL BRACKET
STEERING SHAFT
TURN INDICATOR WIRE COVER
GEAR SHIFT TUBE BRACKET

36-15. Turn signal switch and related parts. (Ford)


TERMINALS
MOULDED TERMINAL BASE
HYDRAULIC STOP LIGHT SWITCH
INSULATING CUP
BRONZE CONTACT DIAPHRAGM
RUBBER SEALING DISC
MASTER BRAKE CYLINDER

36-16. Stop light switch installed on hydraulic brake master cylinder.

STOP LIGHT SWITCH

In order to signal a stop, a brake pedal operated switch is provided which operates the stop light or lights at the rear of the vehicle. On cars equipped with hydraulic brakes, the stop light switch, Fig. 36-16, is attached to the master cylinder so that the contacts are closed by increasing fluid pressure as the brakes are applied.

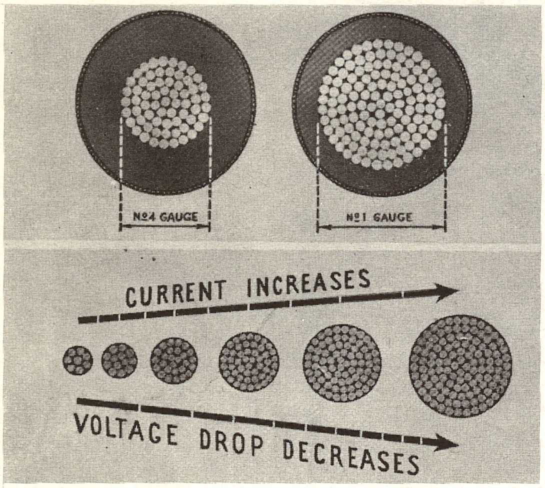
ELECTRIC WIRES AND CABLES

Wires and cables, usually made of copper, are used to carry electricity to the various electrical devices, and equipment on passenger cars and trucks. It is of the greatest importance that wires and cables be of the correct size and have the proper insulation. If the diameter of the wire or cable is too small, its resistance will be too great, and valuable voltage will be lost in overcoming the increased resistance. This in turn will result in poor operation of the particular electrical unit. In the case of lights, they will not provide maximum illumination. In the case of starting motors, lower cranking speeds will result.

Cable size and length determines its resistance. The smaller the diameter of the wire or cable, the greater its resistance, Fig. 35-53. Also, the longer the cable or wire, the greater its resistance will be.

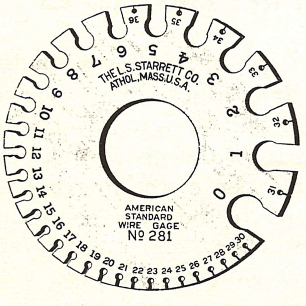
Wire and cable sizes are expressed by a gauge number, which indicates the cross-sectional area (not diameter) of the conductor. The cross-sectional area of wires is given in circular mils. A circular mil is a unit of area equal to the area of a circle one mil in diameter. A mil is a unit of length equal to .001 in. Thus a wire 10 mils in diameter has a cross-sectional area of 100 circular mils (or 78.54 sq. mils).

In the case of cables, Fig. 36-17, which are made up of a number of strands of wire, the cross-sectional area of the cable is equal to the circular mil area of a single strand, times the number of strands.



36-17. Illustrating the gauge of electric cable and the effect of gauge size on voltage drop.

Special gauges, Fig. 36-18, are available for measuring the gauge size of wires. If such gauges are not available, the diameter can be measured by means of a micrometer. Then by checking the diameter obtained in that manner with the accompanying wire table, Fig. 36-19, its gauge size can be determined.



36-18. Typical gauge used for measuring the size of wire.

To determine the gauge size of a cable, count the number of strands. Then measure the diameter of a single strand with a micrometer. In the wire table determine the area in circular mils for that diameter wire. Then multiply the area of the single wire in circular mils by the number of strands in the cable. Locate in the table the area in circular mils that is closest to that value. The gauge size corresponding to the total area in circular mils will be the gauge size of the cable.

Wire Diameter Inches	American Wire Gauge	Circular Mil Area
.4600	0000	211600
.4096	000	167800
.3648	00	133100
.3249	0	105500
.2893	1	83690
.2576	2	66370
.2294	3	52640
.2043	4	41740
.1620	6	26250
.1285	8	16510
.1019	10	10380
.0808	12	6530
.0640	14	4107
.0508	16	2583
.0403	18	1624
.0319	20	1022
.0284	21	810.1
.0253	22	642.4
.0225	23	509.5
.0201	24	404.0
.0179	25	320.4
.0159	26	254.1
.0142	27	201.5
.0126	28	159.8
.0112	29	126.7
.0100	30	100.5
.0089	31	79.7
.0079	32	63.2
.0070	33	50.1
.0063	34	39.7
.0056	35	31.5
.0050	36	25.0

36-19. Wire gauge table.

When comparing cables it must be remembered that the external diameter of a wire or cable has nothing to do with its current-carrying capacity, Fig. 36-20. Thick insulation will make a small gauge wire look much larger. It is therefore important that only the size of the metal conductors be compared, and the way to do that is by means of a wire gauge, or by a micrometer.

BATTERY CABLES

Because the starting motor, when cranking an engine, will draw approximately 250 amp., it is imperative that the cable connecting the battery to the starter be of sufficient gauge to carry such heavy current. For that reason, it is usually made of No. 1, or No. 2 gauge cable. The cable connecting the battery to the ground must also carry the same current. However, as it is grounded, there is no need to have it insulated. It is often made in the form of a flat woven wire strap.

Because of their proximity to the battery and consequent possibility of corrosion, it is important that the cables make good electrical contact with the cable terminals, and that the terminals make good electrical contact with the battery terminals. Any looseness or corrosion between the cable and its terminal, or between the cable terminal and the battery, will result in high resistance and consequent voltage drop.

High resistance between cables and their terminals can be checked easily by means of a voltmeter. With a current of approx. 20 amp. flowing, connect one terminal of a voltmeter to cable, the other to cable terminal. The voltage drop should then be approx. 0.1 volt. Voltage drop in starter to ground circuit should not be more than 0.1 volt.

Formerly, it was common practice to replace cable terminals when they were badly corroded. Most mechanics today will replace the entire cable.

HIGH TENSION CABLE

In order to carry the high voltage to the spark plugs with minimum loss, it is essential that the high tension cables be covered with ample insulation which must withstand heat, cold, moisture, oil, grease, chafing and corona.

Corona is an electrical phenomenon which is not readily visible, but is one of the worst enemies of high tension cable as it deteriorates rubber very rapidly.

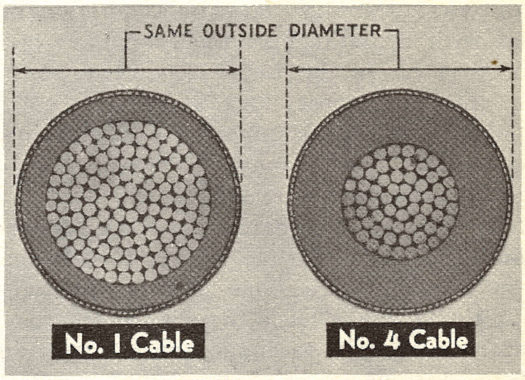
The passage of high tension electricity through a cable builds up a surrounding electrical field. The electrical field liberates oxygen in the surrounding air to form ozone which will attack the rubber insulation if it is not properly protected. This ozone causes the rubber to deteriorate and lose its insulating qualities. Electrical losses result, which in turn will seriously weaken the spark at the plug gap. High quality ignition cable is designed to withstand the effects of corona, also heat, cold, oil, grease and moisture. In recent years great improvements have been made in the insulation of high tension cables.

High tension cable is available in cut lengths designed for installation on the different makes and models of engines. However, in many cases the mechanic makes up the cable set, using the original cable as a guide in cutting the desired lengths. When installing new cable, the individual pieces should be cut as short as possible, but sufficient length should be provided so that sharp bends are avoided. In addition, it is advisable to separate the individual cables as much as possible. Short cables, well spaced, reduce the electrical capacity of the system and thereby improve ignition.

Insulating nipples should always be used at both ends of the ignition cable to reduce leakage and losses due to moisture.

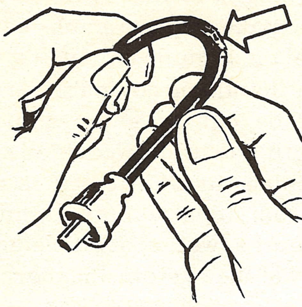
If the cable is run through metal conduit, it is important that the conduit be grounded.

When checking high tension cables, both the insulation and the terminals should be carefully examined. If the cable is carried in a conduit, it should be removed so the entire length of cable can be examined. If the insulation is hard or brittle, it should be replaced. The usual method of checking the insulation is to bend to a small circle, Fig. 36-21, and note if any cracks appear in the insulation. If the end of the copper cable has receded so the insulation extends beyond, it is probably not making good contact with the terminal. In such cases, it is probable that the entire cable has deteriorated and should be replaced.



36-20. The outside diameter of the cable insulation is no gauge of its current carrying capacity. In the illustration both cables have the same outside diameter, but the No. 1 cable has much less resistance and greater carrying capacity than the No. 4 cable.

The spark plug cables should be removed from the distributor cap sockets and each socket should be thoroughly cleaned. Frequently, these sockets have become corroded. It is important that all corrosion is removed, otherwise engine performance will be seriously affected. When replacing the cables, be sure they are pushed to the bottom of the sockets in the distributor. If this is not done, the spark will jump the air gap and cause corrosion and burned contacts.



36-21. If cracks appear in the insulation when it is given a sharp bend, it should be discarded.

RESISTOR IGNITION CABLE

To reduce interference with radio and TV reception, automotive ignition systems are provided with resistance in the secondary circuit. This may be in the form of a resistance unit built into the rotor, or distributor cap, resistance in the spark plugs, or special resistor-type ignition cable may be used. The latter form is being used currently.

Resistor ignition cable consists of parallel strands of linen thread covered with braided rayon thread. This core is then treated with graphite to make it a conductor of the high tension current. This conductor is then covered with insulation.

Because of the material of which it is made, a quick jerk can break the conductor or greatly increase its resistance to such a degree that poor performance will result. When disconnecting a cable from a spark plug or from the distributor, grasp the cable terminal and not the cable. Its resistance can also be increased by severe flexing.

When terminals are applied to resistor type cable, the center staple should be driven into the center of the core to prevent over center arcing.

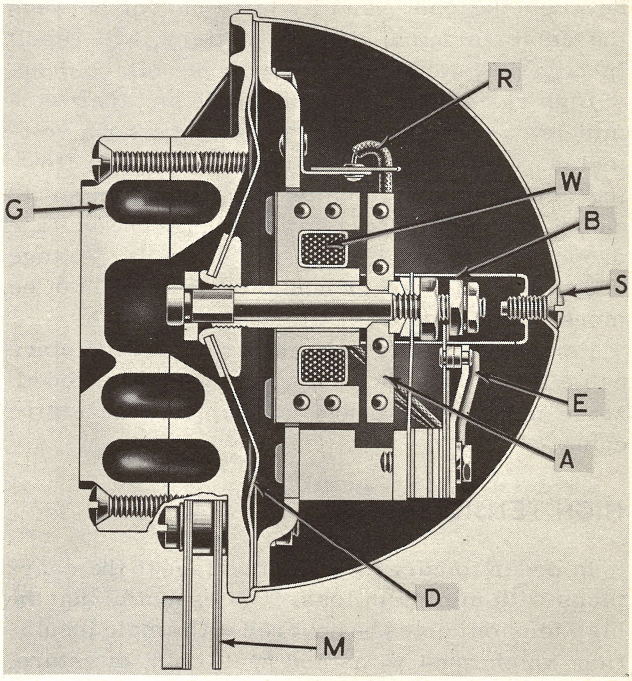
Resistor-type ignition cable can be recognized by the word "Radio" or the letters "TVRS" stamped at intervals on the surface of the insulation.

The resistance of resistor-type ignition cable is approximately 4000 ohms per foot. When checking the resistance of this cable, or when setting ignition timing, do not puncture the wires with a probe as this may cause separation of the conductor, which in turn will induce arcing and quick failure of the cable.

HORNS AND WARNING SIGNALS

Most modern horns consist of a diaphragm, see Figs. 36-22, 36-23, and 36-24, which is vibrated by means of an electromagnet. When the electromagnet is energized, it pulls on an armature that is attached to the diaphragm. Movement of the armature flexes the diaphragm, and opens a set of electrical contacts. As the contacts are in series with the circuit, the current will be turned off and on at a high rate.

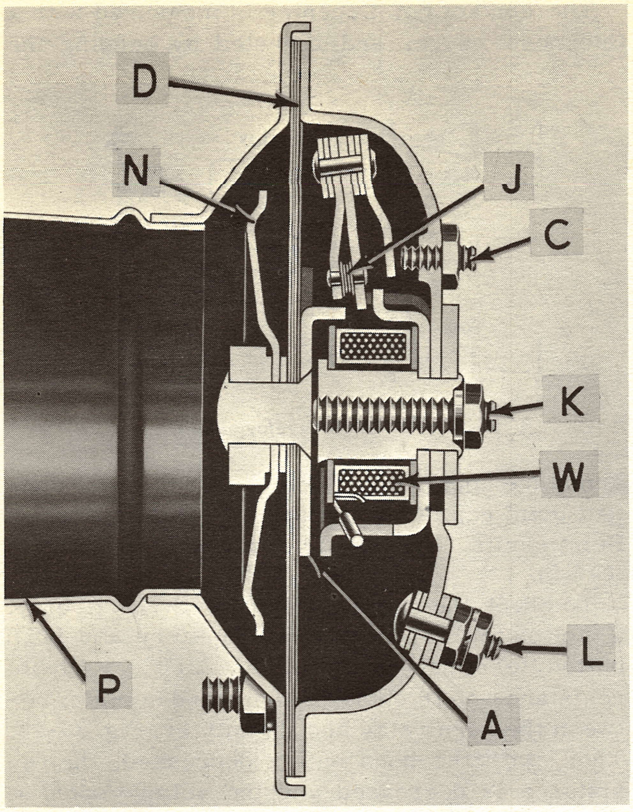
The tone and character of the horn signal is largely dependent on the manner in which the movement of the diaphragm is utilized and also on the stiffness of the diaphragm.



36-22. Details of types HB, HC, HF and HG Auto-Lite horn. (A) Armature. (B) Circuit breaker adjusting screw. (D) Diaphragm. (E) Circuit breaker. (G) Sound ducts. (M) Mounting Springs. (R) Resistor. (W) Winding.

Some types of horns have a resistance connected in series with the magnet winding, Fig. 36-22, or a condenser connected across the horn contacts. As a result, arcing at the points is greatly reduced and point life increased.

The horn should be inspected periodically. Dust and other foreign matter should be wiped from the outside of the horn and projector. If it is rusted or corroded, it should be removed for



36-23. Types HA, HD and HK Auto-Lite electric horn. (A) Armature. (C) Circuit breaker adjusting screw. (D) Diaphragm. (J) Contacts. (K) Striker screw. (L) Horn terminal. (N) Ringer disk. (P) Projector. (W) Winding.

overhaul. Naturally all mounting bolts and electrical connections should be tight. If the horn is not operating, the fuse and wiring should be inspected. Also if a horn relay is being used, that too should be checked.

To test whether a horn is inoperative, connect a jumper wire from the battery to the horn terminal. If the horn still does not operate, provide a good ground for the horn. If the horn then operates, it indicates that the ground connection is at fault.

Two-wire horns will not operate with only the battery jumper wire in place, but require a second jumper wire connecting the other horn terminal to the ground. If the horns operate with these tests, the trouble will be found in the relay, wiring, or horn button.

The usual cause for continuous operation of the horn is a ground in the wiring leading from the horn button to the horn or horn relay.

Because of the relatively heavy current required to operate a horn, the wire selected for horn circuits should be No. 12 or larger.

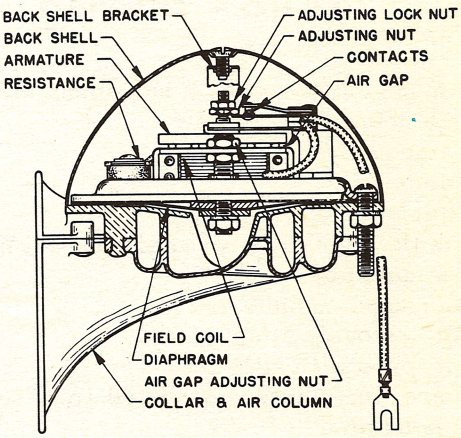
Horns that are inoperative or do not have the correct tone, should be removed for inspection after making sure the difficulty is not in the wiring relay or connections.

The diaphragm of the horn, Figs. 36-22, 36-23 and 36-24, must be free of cracks, and not dented or deformed in any manner. Also make sure the resistor and condenser are in good condition.

When inspecting the horn contact points, care must be exercised not to force them apart as that would result in bending the contact spring. Contact points that are rough and pitted should be replaced, or cleaned and polished with crocus cloth, then washed clean with carbon tetrachloride. On some types of horns, replacement of the contacts necessitates replacement of the entire back assembly.

After cleaning or replacing the contact, and other defective parts, the horn is reassembled, but the horn dome and bracket are left off until after the horn is adjusted. All gaskets must be in place and flange screws and circuit breaker mounting screws must be tight. Make sure the nut on the projector side of the diaphragm is tight. To keep resistance to a minimum, all electrical connections within the horn must be soldered.

The adjustment of the armature gap is critical, and must be in accordance with the specifications for that particular make and model of horn. This gap ranges from .025 to .040 in. Rags or other material should not be stuffed into the projector to muffle the sound as this changes the frequency of vibration and also will give a false current reading when checking the current drawn by the horn. Clamping the flange in a vise will alter tension on the diaphragm, affecting its tone, and there is also the possibility of breakage.



36-24. Sectional view of typical horn. (Delco-Remy)

HORN RELAYS

The horn relay is connected into the horn and battery circuit, Fig. 36-25, to make a more direct connection between the horn and the battery. In that way, the voltage drop in the wiring from the horn to battery is eliminated and higher voltage is available for operating.

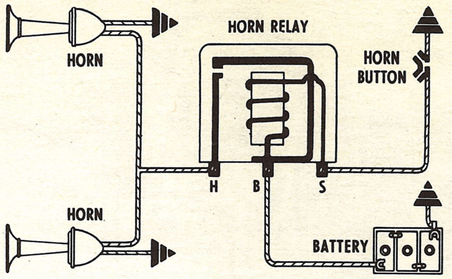
The horn relay consists of a winding on a core above which an armature is placed. The armature is provided with a contact point which meets a stationary contact point.

A typical horn circuit is shown in Fig. 36-25. When the horn button is depressed, the circuit from the battery to the horn relay is completed, and the relay contact points are closed. As shown in the diagram, when the contacts are closed, current direct from the battery is supplied to the horns.

Because of the low price, many mechanics will not attempt to repair a defective horn relay, but will install a new unit. However, there are only three checks and adjustments required: the air gap, point opening, and closing voltage. The air gap and contact point opening checks should be made with the battery disconnected.

Unless the relay has been misadjusted, the air gap will seldom require adjustment. This air gap varies with different models of Delco-Remy relays and ranges from .015 to .045 in. On Auto-Lite units, the adjustment ranges from .012 to .020 in. The air gap is checked with the contact points just touching and adjustment is usually made by bending the lower point support.

The contact point opening is measured with a thickness gauge, and adjusted by bending the armature upper stop. On Auto-Lite units the contact point gap is usually .026 in., while on Delco-Remy units, the setting ranges from .020 to .045 in.



36-25. Horn and horn relay circuit.

To check the closing voltage of the horn relay, a voltmeter is connected to battery and horn button terminal of the relay. Also a variable resistance of 10 ohms is connected in series between the horn relay and the battery, Fig. 36-26. Then, with the horn button depressed, the resistance is decreased and the voltage noted at which the contacts close. Bending the armature spring post down increases the closing voltage, while bending it up will decrease the voltage at which the contacts close.

QUIZ - LIGHTS, LIGHTING CIRCUITS, HORNS

1-How much current does a sealed beam lamp on a 12 volt circuit draw?
  a. 8 ampere
  b. 4 ampere
  c. 12 ampere

2-How is the light output of a sealed beam headlight affected by age?
  a. Decreases rapidly
  b. Not seriously affected
  c. Improves with age

3-How are the wires connected to a sealed beam headlamp?
  a. Pull apart, bayonet type connector.
  b. Soldered connections
  c. Screw type connectors

4-How many terminals are on the outboard lamp of a dual headlamp system?
  a. Three
  b. Two
  c. One

5-What provision is made on modern sealed beam headlamps to assist in aiming the unit?

6-When aiming a sealed beam headlamp, what does the adjustment at the top of the retaining ring control?
  a. Vertical control of beam
  b. Swing beam from side to side

7-In the single wire system of automotive lighting system, what is used for the return of the current to the battery?

8-Give two causes of excessive voltage in the lighting circuit.

9-What is the permissible voltage drop between the battery and the lamp?
  a. 12 volts
  b. 0.6 volts
  c. 1.0 volts

10-What is the purpose of the fuse or overload relay in the lighting circuit?

11-The current limit relay has a single winding of very heavy wire. How is it connected in the circuit?
  a. Parallel
  b. Series
  c. Shunt
  d. Series-parallel

12-What is the purpose of the light relay as used in the headlamp circuit?

13-Which size wire can carry greatest amount of current? No. 16 gauge or No. 4 gauge?

14-What is the purpose of the rheostat used on some types of lighting switches?

15-On cars equipped with hydraulic brakes, where is the stop light switch usually located?

16-Define the term circular mil.

17-What is the diameter of No. 16 gauge wire?
  a. .0508 in.
  b. .0805 in.
  c. .0160 in.

18-What size cable is commonly used to connect the starting motor?
  a. No. 1 or No. 2
  b. No. 000
  c. No. 36

19-High tension ignition cables should be placed as close together as possible.
  a. True   b. False

20-Give a simple test for checking condition of insulation on high tension ignition cable.

21-What is the purpose of ignition resistor cable?
  a. Improve the spark at the spark plugs
  b. Reduce interference with radio and TV sets

22-What causes the diaphragm on a modern horn to vibrate?

23-What is the purpose of condenser in the horn?
  a. Reduce arcing at the contacts.
  b. Reduce the resistance.

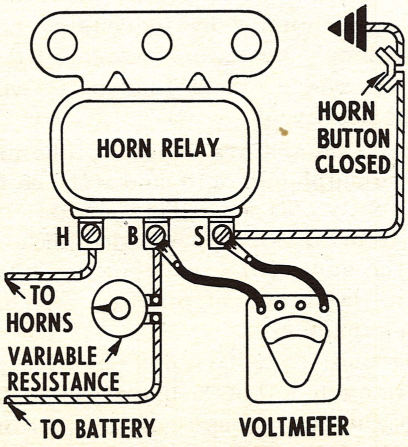
24-What is the approximate range of gap of the armature on an electric horn?
  a. .025 to .040 in.
  b. .060 to .075 in.
  c. .005 to .010 in.

25-What is the purpose of the horn relay?

26-Where is the voltmeter connected when checking the closing voltage of a horn relay?
  a. To the battery and horn button contacts of the relay
  b. To the battery and the horn contact of the relay
  c. To the horn and the horn button contacts of the relay

STORAGE BATTERIES

A lead-acid storage battery, such as shown in Fig. 36-27, is provided to supply a source of power for cranking the internal combustion engine. At the same time, it provides the necessary electrical energy for the ignition system.



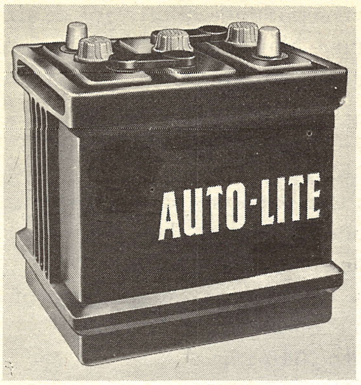
36-26. Checking closing voltage of horn relay.

The battery also acts as a stabilizer to the voltage of the automotive electrical system. In addition it can, for a limited time, furnish current when the electrical demands of the vehicle exceed the generator output.

The lead-acid storage battery is not a storage tank for electricity, but is an electro-chemical device for converting chemical energy into electrical energy. The amount of electrical power in the storage battery is determined by the amount of chemical substances in the battery. When these substances have been used up, they are restored to their original chemical condition by passing an electric current through the battery. This recharging current must pass in the opposite direction to the discharging current.

Each cell of a lead-acid storage battery will produce approximately 2 v. For a 6 v. battery three cells are therefore provided and for a 12 v. battery there are six cells, Fig. 36-28. In each case the cells are connected in series.

Each cell contains an element which is composed of a negative-plate group and a positive-plate group, Fig. 36-29. The plate is formed of lattice-like grids of an alloy of lead and antimony, and the grids are filled with special lead-oxide pastes. These pastes after processing to make them solid but porous, become the



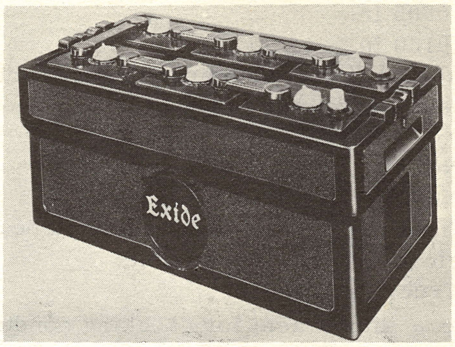
36-27. Typical starting battery, 6-volt, used for automotive starting and lighting.

active materials of the battery after it has been charged.

The amount of current that can be produced by a storage battery is determined by the active area and weight of the materials in the plates, and by the quantity of sulphuric acid in the electrolyte. After most of the available active materials have been activated, the battery can produce little or no current, and is said to be discharged. Before it can provide current again it is necessary to restore the battery plates to their original chemical condition. This is accomplished by passing an electric current, from an external source, through the battery. The charging current must flow through the battery in a direction opposite to the current flow from the battery. This results in a reversal of the discharge chemical reactions in the storage battery, so the chemicals are restored to their original active condition.

The construction of an automotive type lead-acid storage battery, Fig. 36-29, is relatively simple. The positive and negative plates, Fig. 36-30, consist of special active materials contained in cast grids of lead-antimony alloy. These grids are rectangular, flat, lattice-like castings with relatively heavy frames and a mesh of vertical and horizontal wires. The positive plates contain lead peroxide which is chocolate brown color, while the negative plates contain sponge lead which is gray in color.

Each cell of a storage battery is made of alternate positive and negative plates. A plate group is made by welding (lead burning) a number of plates of the same polarity to a plate strap. The plate strap also includes a vertical terminal post, so the cell can be connected to the other cells forming the battery. Plate groups of opposite polarity are interlaced, so that negative and positive plates alternate. Usually negative plate groups contain one more plate than the positive plate group within the same cell. As a result there will be a negative plate on both sides of the plate group. The reason for this is that the chemicals forming the negative plates are not as active as those forming the positive plates. By providing the additional area, the chemical activity of the positive and negative plates are more nearly equalized. Each cell will, therefore, have an uneven number of plates and storage batteries are known as 13, 15, 17, etc. plate batteries. The greater the number of plates, or plate area, the greater the capacity of the cell, and the greater the current that will be available.



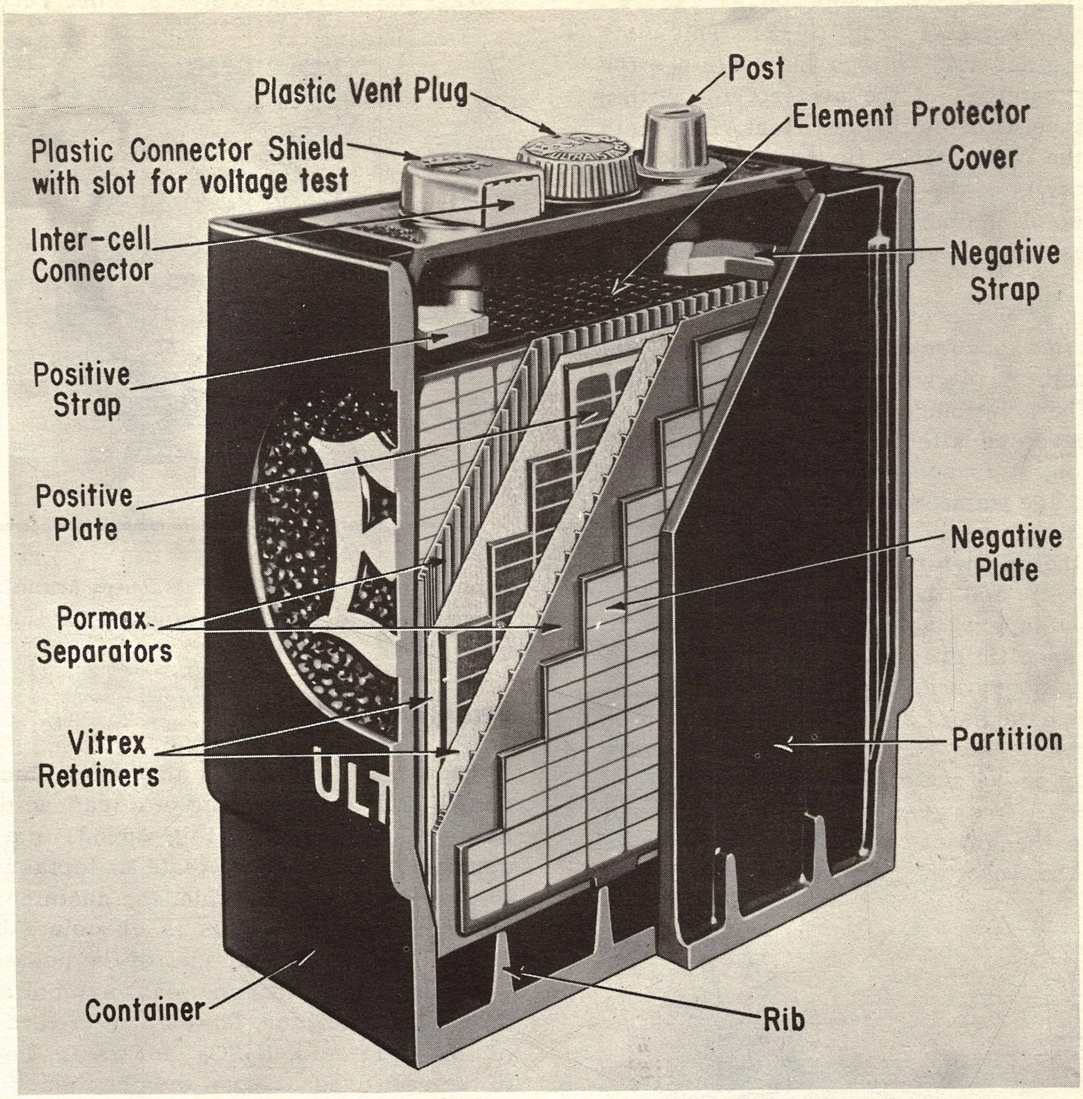
36-28. Heavy duty 12-volt automotive storage battery, 25 plates per cell and 168 amp. hr. at the 20 hour rate.

To insure against adjacent plates touching each other, separators are placed between them, Figs. 36-29 and 36-30. These separators are made of sheets of porous non-conducting material such as chemically treated wood, porous rubber, resin-impregnated fiber and glass fiber. Separators usually have ribs on one side facing the positive plate. This provides a greater volume of acid next to the positive plate and improves efficiency by increasing acid circulation. Some separators are also designed to aid in the reduction of loss of active material from the positive plate.

Battery separators must be chemically resistant to sulphuric acid, and at the same time be mechanically strong. They must be porous enough to permit free passage of the electrolyte, and at the same time, prevent the active chemicals in the plates from touching each other through expansion.

The group of positive and negative plates are placed in each cell of the battery case. The lower edges of the cell groups rest on ribs or element rests, Fig. 36-29, and the space between the bridges are known as sediment chambers, where loosened material from the plates may accumulate without short circuiting the plates.

The battery container or case, in which the groups of plates are held, is of one piece molded


Plastic Vent Plug
Post
Element Protector
Plastic Connector Shield with slot for voltage test
Cover
Inter-cell Connector
Negative Strap
Positive Strap
Positive Plate
Negative Plate
Pormax Separators
Vitrex Retainers
Partition
Container
Rib

36-29. Cut-away section of automotive starting battery.

type, usually of hard rubber or bituminous composition. In addition to withstanding the action of sulphuric acid, it must be mechanically strong and not be affected by wide variations in temperature.

With the plates in place in the battery case, cell covers of molded hard rubber or similar material, are fitted over the terminal posts of the plate groups. Vents are provided in the covers, so the cells can be filled with electrolyte and, periodically, with water that has been lost through evaporation. In addition, the vents permit gases to escape.

There are many different types of vent caps. Some of the caps of recent design have materially reduced evaporation of water, so it requires replenishment only at long intervals.

After the covers are installed, the individual cells are connected together in series and finally asphaltic sealing compound is poured around the edges of the covers so that leakage is prevented.

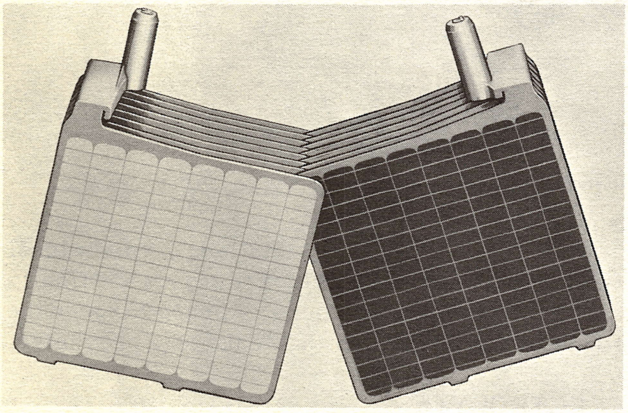
ELECTROLYTE

After the battery is completely assembled, it is filled with the electrolyte. In lead-acid storage batteries this is a fairly concentrated solution of sulphuric acid and water having a specific gravity of 1.290 at 80 deg. F. Specific gravity is the weight of a given volume of a liquid, divided by the weight of an equal volume of water at a temperature of 39.1 deg. F. When an electrolyte has a specific gravity of 1.290 it is 1.290 times as heavy as an equal volume of water, when both liquids are at the same temperature.

The specific gravity of a solution is measured by using a hydrometer, Fig. 36-31. This consists of a glass tube with a bulb syringe for sucking up samples of the electrolyte. Within the glass tube is a calibrated float. The depth to which the float sinks is a measure of the specific gravity of the solution. The float sinks further in solutions having a low specific gravity than it does in solutions having a high specific gravity.

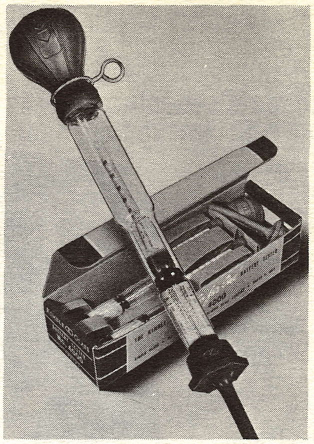
The float is made of glass with a scale and its weight is accurately determined by the manufacturer, so it will indicate the specific gravity of the solution.

As temperature affects the specific gravity of a solution, it is necessary to take the temperature at the same time the specific gravity is taken. The more expensive hydrometers have a built-in thermometer so the temperature can be measured, and the necessary correction made. The temperature correction amounts to about .004 specific gravity for every 10 deg. F. change in temperature. The specific gravity of various percentages of sulphuric acid at various temperatures is shown in Fig. 36-32. Basically for every 10 deg. F. of electrolyte temperature above 80 deg., four gravity points (.004) must be added to the gravity reading. This compensates for the loss of gravity caused by the expansion of the solution as its temperature increases. For every 10 deg. of electrolyte temperature below 80 deg., four gravity points must be subtracted from the gravity reading. This compensates for the gain in gravity due to the contraction of the liquid, as its temperature decreases.



36-30. Negative (left) and positive (right), storage battery plates (Willard), showing how the plates alternate. Note also the "feet" on the bottom edge of the plates which rest on the element rests formed on the bottom of the battery container.

Formerly 60 deg. and 70 deg. were used as the basis for measuring the specific gravity of storage battery electrolytes. More recently the American Association of Battery Manufacturers adopted 80 deg. as the standard for such measurements.



36-31. Battery hydrometer with temperature correction.

CHEMICAL ACTION

The chemical actions that take place during charging and discharging of a lead-acid storage battery are shown in Fig. 36-33. In a charged condition, the positive plate material is essentially pure lead peroxide, the chemical symbol of which is PbO_2. This is chocolate brown in color. The active material of the negative plate is spongy lead, the chemical symbol being Pb, and is gray in color. The electrolyte is a solution of sulphuric acid, H_2SO_4, and water. The voltage of the cell depends upon the chemical difference between the active materials and slightly upon the concentration of the electrolyte.

When an electric load is connected to the battery, current will flow, and this current is produced by the chemical reactions between the active materials of the two kinds of battery plates and the sulphuric acid. As shown in Fig. 36-33, the oxygen in the PbO_2 combines with the hydrogen, H_2, from the sulphuric acid to form water, H_2O. At the same time the lead, Pb, in the lead peroxide combines with the SO_4, portion of the sulphuric acid to form lead sulphate, $PbSO_4$.

A similar action takes place at the negative plate where the lead Pb of the negative active material combines with the SO_4 of the sulphuric acid to form $PbSO_4$, lead sulphate.

While there is an electric load on the battery, lead sulphate is formed on both positive and negative plates in the battery, and the elec-

Sulphuric Acid %	10	20	30	40	50	60	70	80	90	100	110	120	130
COMPLETELY DISCHARGED													
10.2			1.076	1.074	1.072	1.070	1.068	1.066	1.063	1.060	1.057	1.055	1.052
11.7			1.086	1.084	1.082	1.080	1.078	1.075	1.072	1.070	1.067	1.064	1.061
13.1			1.096	1.094	1.092	1.090	1.088	1.085	1.082	1.079	1.076	1.073	1.070
14.4		1.109	1.107	1.105	1.103	1.100	1.097	1.095	1.092	1.089	1.086	1.083	1.080
15.7		1.120	1.118	1.115	1.113	1.110	1.107	1.104	1.101	1.098	1.096	1.092	1.089
17.1		1.131	1.129	1.126	1.123	1.120	1.117	1.114	1.111	1.108	1.105	1.102	1.099
18.4		1.142	1.139	1.136	1.133	1.130	1.127	1.124	1.120	1.118	1.114	1.111	1.108
19.7	1.156	1.153	1.149	1.146	1.143	1.140	1.137	1.134	1.130	1.127	1.124	1.120	1.117
BARELY OPERATIVE													
21.0	1.166	1.163	1.160	1.156	1.153	1.150	1.147	1.143	1.140	1.137	1.133	1.130	1.127
22.3	1.177	1.173	1.170	1.167	1.163	1.160	1.157	1.153	1.150	1.146	1.143	1.140	1.136
23.5	1.187	1.183	1.180	1.177	1.173	1.170	1.167	1.163	1.159	1.156	1.152	1.148	1.145
ONE FOURTH CHARGED													
24.7	1.198	1.194	1.190	1.187	1.184	1.180	1.176	1.173	1.169	1.165	1.162	1.158	1.154
26.0	1.208	1.204	1.200	1.197	1.194	1.190	1.186	1.183	1.179	1.175	1.171	1.168	1.164
27.2	1.218	1.214	1.211	1.207	1.204	1.200	1.196	1.193	1.189	1.185	1.181	1.177	1.174
28.5	1.228	1.224	1.221	1.217	1.214	1.210	1.206	1.203	1.199	1.195	1.191	1.187	1.183
ONE HALF CHARGED													
29.7	1.238	1.234	1.231	1.227	1.224	1.220	1.216	1.212	1.208	1.204	1.200	1.196	1.193
31.0	1.249	1.246	1.242	1.238	1.234	1.230	1.226	1.222	1.218	1.214	1.210	1.206	1.202
32.2	1.259	1.256	1.252	1.248	1.244	1.240	1.236	1.232	1.228	1.224	1.220	1.216	1.212
THREE FOURTHS CHARGED													
33.3	1.270	1.266	1.262	1.258	1.254	1.250	1.246	1.242	1.238	1.234	1.230	1.226	1.222
34.5	1.280	1.276	1.272	1.268	1.264	1.260	1.256	1.252	1.248	1.244	1.240	1.236	1.232
35.8	1.290	1.286	1.282	1.278	1.274	1.270	1.266	1.262	1.258	1.254	1.250	1.246	1.242
FULLY CHARGED													
37.0	1.300	1.296	1.292	1.288	1.284	1.280	1.276	1.272	1.268	1.264	1.260	1.256	1.252
38.1	1.310	1.306	1.302	1.298	1.294	1.290	1.286	1.282	1.278	1.274	1.270	1.266	1.262
39.2	1.320	1.316	1.312	1.308	1.304	1.300	1.296	1.292	1.288	1.284	1.280	1.276	1.272

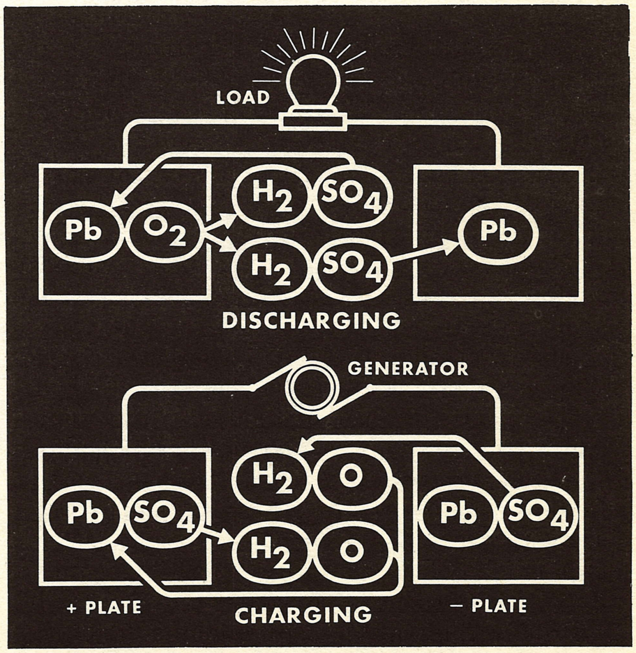
36-32. Specific gravities of various percentages of sulphuric acid at various temperatures.

trolyte becomes diluted with water.

As the discharge continues, the accumulation of lead sulphate in the plates, and the dilution of the electrolyte brings the chemical reactions to a halt. At low rates of discharge (small current), the reactions are more complete than at high rates, as more time is available for the materials to come into contact. When the chemical action can no longer take place, the battery is said to be discharged.

During charge, the chemical reactions are basically the reverse of those which occur during discharge. The $PbSO_4$, lead sulphate, on both plates is split up into Pb and SO_4, Fig. 36-33, while the water H_2O is split into hydrogen H, and oxygen O_2. The passage of the charging current, which is in the reverse direction to the discharging current, forces the SO_4 from the plates and combines with the H_2 to form H_2SO4, sulphuric acid. At the same time the oxygen O_2, enters into chemical combination with the lead at the positive plate to form PbO_2.

The specific gravity of the electrolyte de-



36-33. Chemical action in a lead storage battery.

creases during discharge for two reasons. Not only is the sulphuric acid used up, but new water is formed. As the water is formed at the positive plates and diffuses slowly through the electrolyte, the positive plates are more likely to be damaged during freezing weather. When the battery is fully charged, the specific gravity of the solution increases, sulphuric acid is formed, and water is used up. As a result there is little danger of a fully charged battery freezing.

Specific gravity of the electrolyte may continue to rise for some time after a battery has been quick charged, as the newly formed acid requires time to diffuse from the plates to the electrolyte. Specific gravity readings taken while a battery is gassing will be erroneously low.

VOLTAGE VARIATIONS

Battery voltage and specific gravity vary while it is being charged and it is therefore important that these be checked. Starting batteries are designed to maintain a definite relationship between charging voltage and charging rate and any variation from standard conditions will result in unsatisfactory battery service.

The relationship between charging voltage and charging rate in a battery in various states of charge is shown in Fig. 36-34. From the chart it will be noted that as the specific gravity increases, the charging voltage must be increased if the same charging current is to be maintained.

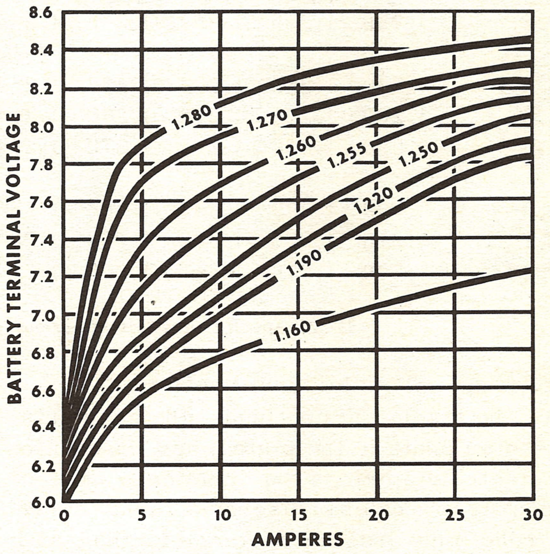
The charging voltage is determined entirely by the battery until the charging voltage reaches the limit as set by the setting of the voltage regulator. Another point shown by Fig. 36-34 is that the charging rate is reduced gradually if the charging voltage is limited. Whenever the charging voltage reaches the limit for which the regulator is adjusted, the voltage regulator operates to limit the voltage to that value. But as the battery comes up to charge, increased voltage is required to maintain the charging current at the same value. As additional voltage is no longer available, the charging current decreases, and in that way adjusts itself to the gradual change in the state of charge. For example, in a battery having a specific gravity of 1,220 and a charging voltage of 7.2, the battery will charge at approximately 12 amp. (Fig. 36-34). When the specific gravity has increased to 1.250, the charging current will have dropped to 10 amp. and at 1.255 the charging current will be approximately 6 amp.

From Fig. 36-34 it can also be noted how a small change in charging voltage will greatly increase the charging current. For example, on a 1.250 battery increasing the voltage regulator setting from 7.2 to 7.5 will increase the charging current from 10 to 15 amp. A high final charging rate will often ruin a battery.

A battery in normal use tends to operate at lower and lower voltages for a given charging current. Batteries which have not been used for a long period, tend to operate at higher voltages for a given charging rate. Such batteries usually become discharged very quickly when placed in service. The maximum allowable setting of the regulator can be ineffective on such batteries as they tend to heat excessively when charged at higher rates. It is advisable to charge such batteries at a very low rate until there is no further increase in specific gravity readings.

BATTERY VOLTAGE AND CAPACITY

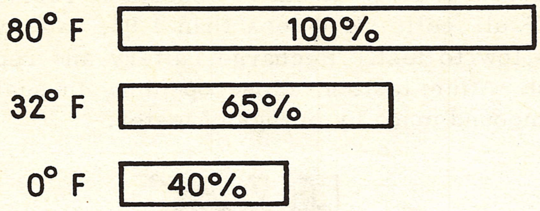
The open circuit voltage of a fully charged storage battery cell is 2.1 volt for acid of approximately 1.280 sp. gr. That is true regardless of the number of plates in the cell or their area. The voltage is determined only by the character of the chemicals in the plates and the specific gravity of the electrolyte. A 6 v. battery will therefore be made up of three cells, Fig. 36-27, connected in series and a 12 v. battery, Fig. 36-28, will consist of six cells.



36-34. Voltage variation with different battery conditions and charging rates. (6 volt system).

The capacity, that is the amount of current it will deliver, depends on the number and area of the plates in the cell and also on the amount of acid present. In other words, cells having a large number of plates will deliver more current than cells having a smaller number. Automotive starting batteries are built with thin plates to provide maximum plate area in order that the electrolyte may have quick access to as much active plate area as possible.

Battery capacity drops rapidly as the temperature is reduced. The reason for this is that the battery is an electro-chemical device and, as is the case with virtually all chemical actions, it is aided by heat. For example, as shown in Fig. 36-35, if the capacity or cranking power of a battery at 80 deg. is given as 100 per cent, at 32 deg., the capacity will be only 65 per cent and at 0 deg. only 40 per cent.

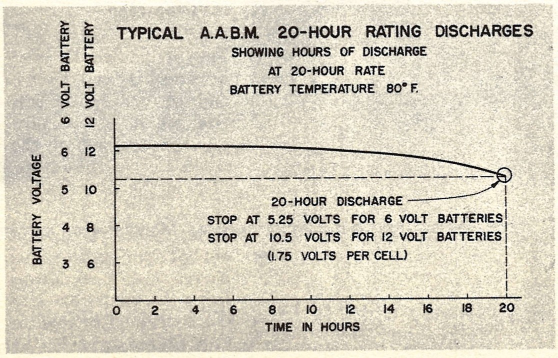


36-35. Comparing the cranking power of a fully charged battery at different temperatures.

BATTERY RATINGS

There are two ratings for automotive starting and lighting batteries which have been incorporated in the standards of the Society of Automotive Engineers, the Association of American Battery Manufacturers and the United States Government.

The 20 hour rating in ampere hours indicates the lighting ability of the battery. The fully charged battery is brought to a temperature of 80 deg. F. and is then discharged at a rate equal to 1/20 of the published 20 hour capacity in ampere hours. For example, a battery rated by the manufacturer as a 6 v. 100 A.H. capacity would be discharged at 1/20 of 100 or 5 amp., until the voltage has dropped to 5.25 volts. The number of hours required for the discharge, multiplied by the rate of 5 amp., is its 20 hour rating, Fig. 36-36.

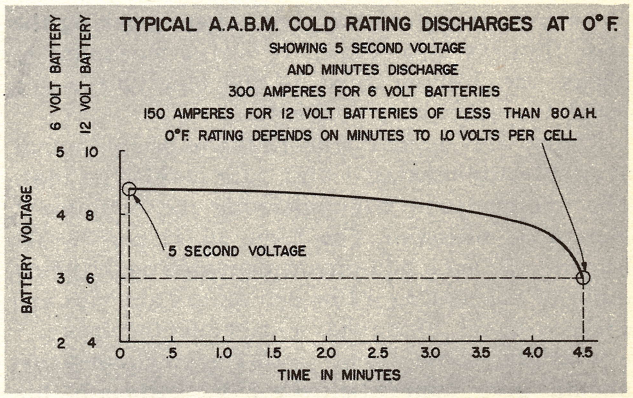


36-36. Twenty hour rating discharges.

Cold Rating at 0° F.: All 6 and 12 v. batteries of 80 ampere hours capacity and more, are discharged at 300 amperes, while 12 v. batteries of less than 80 ampere hours capacity are discharged at 150 amperes at a temperature of 0° F.

These ratings indicate the cranking ability of a fully charged battery at low temperatures, and are expressed in two ways:

1. By the terminal voltage of a fully charged battery taken 5 seconds after the start of a discharge rate as indicated above with an electrolyte temperature of 0° F.
2. By the number of minutes required for the battery to reach a terminal voltage equivalent to 1.0 volt per cell when discharged at the rate indicated above with an electrolyte temperature of 0° F. at the start, Fig. 36-37.



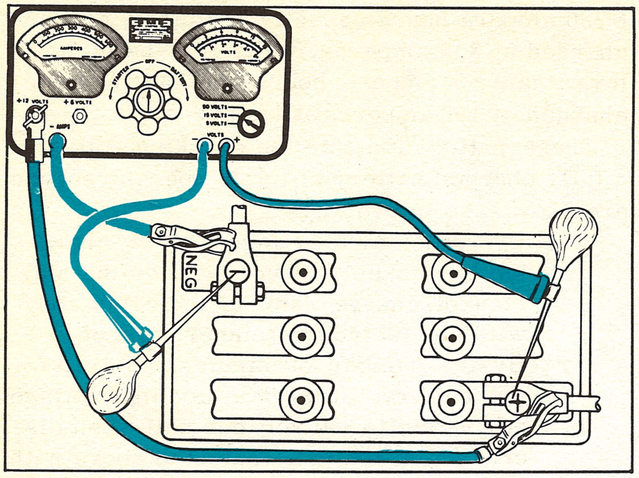
36-37. Cold rating discharge test.

BATTERY TESTING

There are several methods used to test the condition of a storage battery. In general these include the measurement of the specific gravity by means of a hydrometer, Figs. 36-31 and 36-40, as previously described; measurement of cell voltage, Fig. 36-39; measurement of cell voltage during high discharge, Fig. 36-38.

Checking the condition of a battery with a hydrometer should not be done immediately after water has been added to bring the electrolyte to the desired level. Such measurements should be made before the water is added, in order to obtain a representative sample. If the level is too low to obtain a sample, water should be added as needed, and then after the battery has been operated for a sufficient time to thoroughly mix the water with the electrolyte, the sample should be taken with the hydrometer.

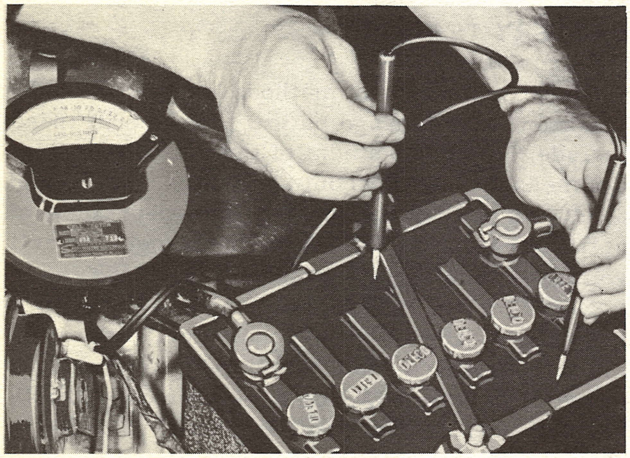
Hydrometer readings should not be taken while the battery is gassing as this would affect the accuracy of the reading.



36-38. *High rate discharge connections.*

As previously pointed out, when checking the specific gravity of a cell, it is also necessary to check the temperature of the electrolyte and make the necessary correction.

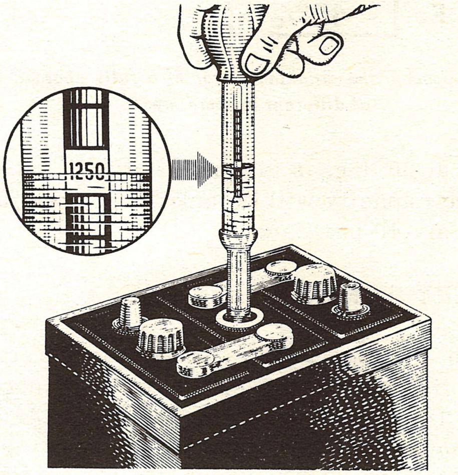
There are many different types of equipment available for making a high rate discharge test. The instructions accompanying the equipment should be followed. See Figs. 36-41 and 36-38. In general, such equipment operates on the principle of connecting a low resistance across each cell for about 30 seconds and measuring the voltage at the same time. Cells in good condition should give approximately 2 v., although this will vary with different equipment. There should be less than 0.2 v. variation between cells.



36-39. *A voltmeter with 0.01 volt divisions is needed to make an open circuit test.*

The light load battery test is claimed to be simpler and more conclusive than the hydrometer test. A voltmeter, having 0.01 volt divisions is needed, Fig. 36-39. The procedure is to place a load on the battery for 3 seconds by closing the starter switch. If engine starts, turn off ignition. Turn headlamps on (low beam), with lights still on, measure voltage of each cell. If any cell reads 1.95 volts or more and the difference between the highest and lowest cell is less than .05 volts, the battery is good. If any cell reads 1.95 volts or more, but there is a difference of 0.05 volts or more between the highest and lowest cell, the battery should be replaced.

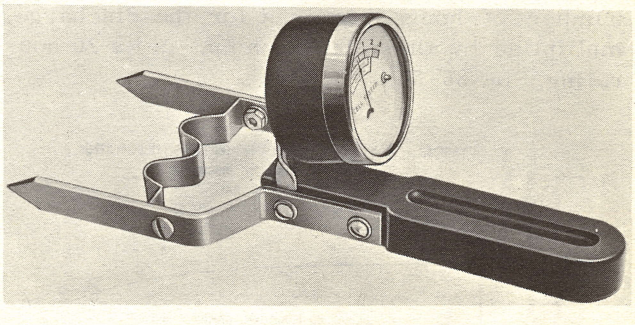
If all cells read less than 1.95, battery is too low to test. Recharge battery and repeat test. After testing, close openings in sealing compound made by prongs of tester.



36-40. *Measuring the specific gravity of a starting battery with a hydrometer.*

BATTERY WATER

Water for use in automotive batteries may be a good grade of drinking water, excluding mineral water. It is advisable to use distilled water, or other water that is free from impurities.



36-41. *Hand type, high rate discharge used for checking one cell at a time.*

Check batteries that require excessive water, as this is usually an indication that the charging rate is too high.

CHECKING CABLE RESISTANCE

Battery cable and terminal connections may be tested with equipment comprising a voltmeter (5 v. maximum), ammeter of 300 or more capacity, and a carbon pile rheostat having a minimum capacity of 300 amp. connected in series with the ammeter.

Connections are as shown in Fig. 36-42, in which the ammeter and rheostat are connected in series within the case. Connect ammeter positive lead to battery terminal stud on junction block. Connect the negative lead to one side of the rheostat, and the other side of the rheostat to a ground on the engine. Attach the voltmeter leads to probes. Attach one voltmeter probe to terminal stud on junction block, and the other to the center of positive battery post. Adjust rheostat until ammeter reads 200 amp. Voltage drop should not exceed 0.2 v. Repeat the test with the voltmeter connected to the ground and to the negative terminal of the battery. Reading should not exceed 0.2 v. Be sure to turn off rheostat between each test.

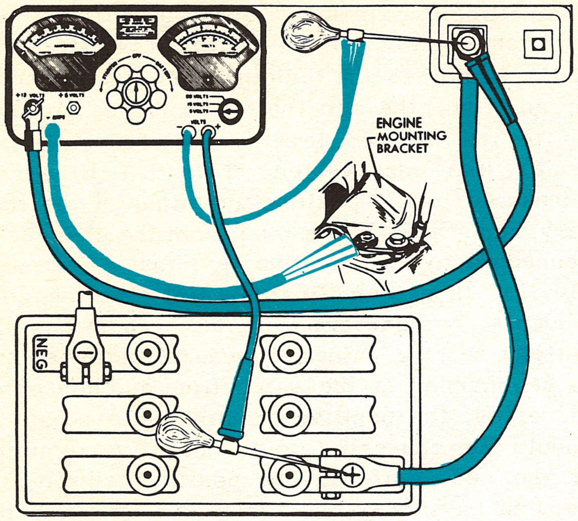
BATTERY CHARGING

Only direct current can be used for charging batteries, and some method must be provided for controlling the amount of charging current. Before placing a battery on charge, the exterior of the battery and the terminals must be cleaned. In addition, the electrolyte must be brought up to the desired level. When charging batteries, the positive lead from the charger is connected to the positive terminal of the battery, and the negative lead from the charger is connected to the negative terminal of the battery. It is extremely important that the connections be correctly made; otherwise the battery will be ruined. If several batteries are to be charged at the same time and connected in series, the positive terminal of one battery should be connected to the negative terminal of the next battery. The positive terminal of the end battery of the series is then connected to the positive terminal of the charger, and the negative terminal of the series of batteries is connected to the negative terminal of the charger.

STORAGE BATTERY TESTING CHART

Hydrometer Test 80 Deg. F.	Condition	Remedy
More than 1.300 Sp. Gr.	Specific Gravity too high	Adjust Specific Gravity
1.250 to 1.295	Probably Good	If variation among cells is less than 0.015 Sp. Gr. no correction is required. If greater than that amount give high rate discharge test. If cells test O. K. recharge and adjust specific gravity of cells.
1.225 to 1.250	Fair	Battery should be recharged. Check operation of voltage regulator. Also check electrical system for loose connections, shorts, grounds and corroded terminals.
Less than 1.225	Poor	Recharge battery. Check voltage regulator, also electrical system for loose connections, shorts, grounds and corroded terminals.
Cells show more than .025 variation in Sp. Gr.	1. Short in low cell 2. Loss of electrolyte 3. Cracked cell partition	Recharge battery at approximately 7 amp. until gravity readings show no increase in three successive readings taken 1 hour apart. Adjust specific gravity of cell. Make a high rate discharge test 12 hours after charging. If more than 0.15 volts difference is shown on cell, battery is no longer serviceable.

The terminals of storage batteries are marked so they can be easily distinguished. The positive terminal is usually marked with a "P," "Pos," or "+." Negative terminals are marked "N," "Neg," or "-." In addition, the positive terminal of the battery is larger in diameter than the negative terminal. In case the markings have been erased, the polarity can be determined by dipping leads from the battery in a weak solution of sulphuric acid. More gas bubbles will collect around the negative lead than around the positive. The same procedure can be used to determine the polarity of the charger.



36-42. *Battery cable test connections.*

Most commercial electricity is of the alternating type. In such cases it is, of course, necessary to convert the alternating current to direct, before it can be used for battery charging purposes. The usual methods used in converting alternating to direct current are motor-generators, tungar bulb rectifiers, and dry disk-type rectifiers.

The constant current method of charging batteries is one method that is used extensively. That method is particularly advantageous where the condition of the battery is not known.

The charging rate varies with different conditions; however, a safe rate would be equal to 1/2 of the number of plates in the cell. For example, the charging current in amperes for a 13 plate cell would be 6 1/2 amp., for a 17 plate cell, 8 1/2 amp. When several batteries of different sizes are connected in series for charging, the charging current is determined by the size of the smallest battery in the series.

During charge, the temperature of batteries should be watched carefully. Should the temperature approach 110 deg. F., the charging rate should be reduced.

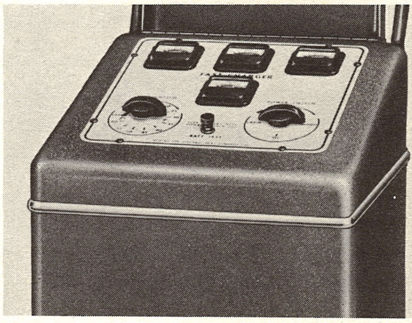
Many storage batteries are fitted with filler plugs of the non-overfill type. In such cases, the electrolyte may be forced from the cell during charge when the vent plugs have been removed, so that a hydrometer reading can be taken. This tendency can be overcome by placing a small stick in the vent hole so that the non-overfill device is held in the open position while taking hydrometer readings.

Vent plugs on batteries with non-overfill devices should be screwed tightly in place during charge.

To check the progress of the charge, hydrometer readings should be taken every hour. The battery is fully charged when the cells are gassing freely, and there is no increase in hydrometer reading for three successive hourly readings. Excessive charging will damage the battery, particularly the positive plates. Depending on the charging rate, most batteries can be charged in 12 to 16 hours. Batteries with sulphated plates will require a longer period.

Constant Potential chargers, as the name implies, maintain the same voltage on the batteries throughout the period of the charge. As a result, the current is automatically reduced as the battery approaches full charge. Batteries in good condition will not be damaged by this method of charging. However, a badly sulphated battery may not come up to charge when the Constant Potential method is used. With this method of charging, battery temperature may rise rapidly, and it is important that frequent checks be made of the temperature.

High Rate Battery charging is a relatively new method. Prior to 1945 only low charging rates were advocated as it was believed that high rates would damage the battery plates. However, by using a high rate charger, batteries can be charged in approximately 30 minutes. As a result, the method has become popular as it permits charging the battery while the customer waits. In addition it has reduced or eliminated



36-43. *This fast charger with a capacity of 100 amp. includes an individual cell analyzer.*

the necessity of a shop having on hand a number of batteries which may be rented to the car owner, while his original battery is being charged.

High charging rates can be used provided the temperature of the electrolyte does not exceed 125 deg. F., and does not cause excessive gassing and loss of electrolyte. In the case of export batteries, being made "wet" from the dry state, the maximum temperature should not exceed 110 deg. F.

Most high rate battery chargers, Figs. 36-43 and 36-44, are of the Constant Potential type and are designed to provide an initial charging rate of 80 to 100 amp. Some types of high rate chargers are equipped with a time cut-off or temperature limiting device, so that electrolyte temperature cannot exceed 125 deg. F. In other words, should the temperature reach 125 deg. F., the charger is shut off automatically.

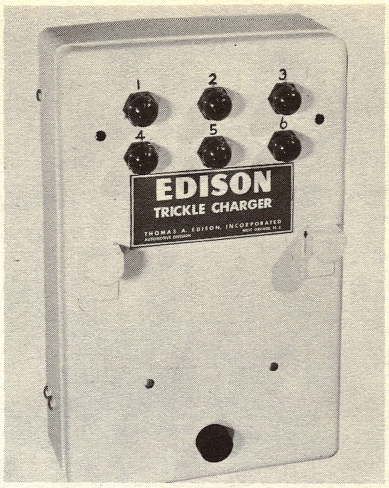
FOX
Powercharger
6-12

36-44. One type of fast charger.

Trickle Chargers, Fig. 36-45, are designed to charge batteries at a rate of approximately 1 amp. They are used primarily for maintaining display and stocks of batteries in a fully charged condition. While the charging rate is extremely low, batteries can be damaged if left on a trickle charge for long periods. Common practice is to leave the batteries on a trickle charge during the day and take them off charge during the night. In that way danger of severe overcharging is eliminated.

BATTERY REPAIRING

Because of high costs of labor and parts, automotive storage batteries are today seldom repaired. Instead, the defective unit is replaced with a new battery. A battery in normal service and properly cared for will usually give satisfactory performance for 12 to 24 months; although it is not unusual for a battery to operate for even longer periods.



36-45. One type of trickle charger designed particularly for the car owner. Other types are available for maintaining stocks of batteries in good condition.

However, under some unusual conditions it may be necessary to disassemble a battery for examination to determine the cause of the failure. A battery in which the water level was not maintained is shown in Fig. 36-46.

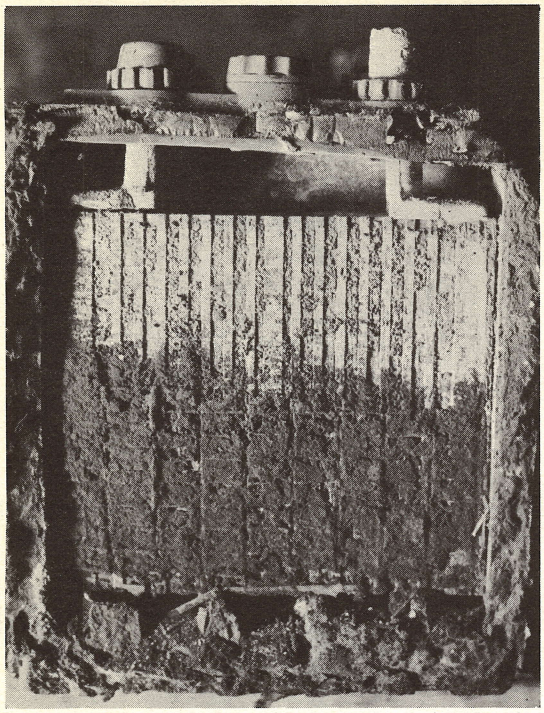
Before opening a battery it is important to mark on the battery case the position of the positive and negative terminals. In addition, factory code markings should be recorded. Specific gravity readings of the individual cells should also be recorded for future reference.

If the battery case is cracked, or if the three cells are to be removed as a unit, the sealing compound is cut from the container walls with a hot putty knife. The three elements are then lifted from the case. Element shims should be kept with the elements to insure a snug fit when the cells are reinstalled.

To remove a single element, the cell connectors are cut with a hack saw. Lead will tend to clog the teeth of the saw, but this can be prevented by first running the teeth of the saw through some sealing compound. The sealing compound, surrounding the cell, is then cut with a hot putty knife, permitting the cell to be pulled from the container.

DRY CHARGED BATTERIES

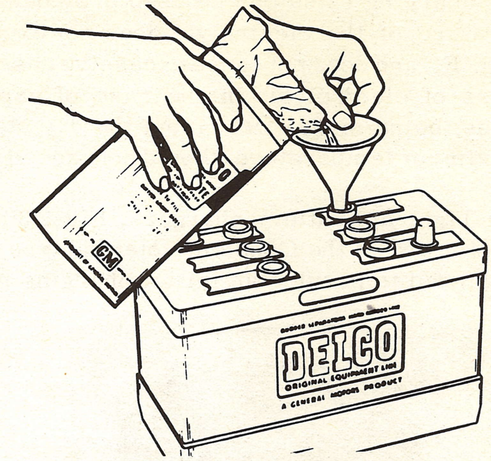
A dry charged starting battery contains no electrolyte until it is placed in service. The cell elements are given an initial charge on special equipment at the factory. They are then thoroughly washed and dried and assembled into battery cases.



36-46. This battery was ruined because the level of the electrolyte was not maintained.

A dry charged battery will retain its full charge indefinitely as long as moisture does not enter the cells. When ready for service, the electrolyte (shipped in individual plastic containers) is poured into each cell and the battery is ready for use.

When filling a dry charged battery with electrolyte, the manufacturers advise that protective glasses be worn. The procedure is to remove the vent plugs and discard the white restrictors found in the vent openings. With the electrolyte container right side up, remove the lid, then unfold the top of the plastic bag which contains the electrolyte. Do not attempt to remove the plastic bag from the carton. The bag is sealed to the container, and any attempt to remove the bag may rupture it and spill the acid. Cut a small opening in a corner of the double-walled bag. A large opening will cause the acid to spatter. Using a glass or acid-proof funnel fill each battery cell with electrolyte as shown in Fig. 36-47. The cell is correctly filled to the split ring at the bottom of the vent well. After filling cells, wait five minutes, then if level has fallen, add electrolyte to bring to proper level.



36-47. Filling a dry charged battery with electrolyte.

The drawings, Fig. 36-48, show typical symbols as commonly used in electrical wiring diagrams.

QUIZ - STORAGE BATTERIES

1-What is a lead-acid storage battery?
  a. A storage place for electricity
  b. A converter of chemical energy to electrical energy

2-How much voltage can be obtained from a single cell of a storage battery?
  A. About 2 volts
  b. About 6 volts
  c. About 12 volts
  d. Varies with size of plates

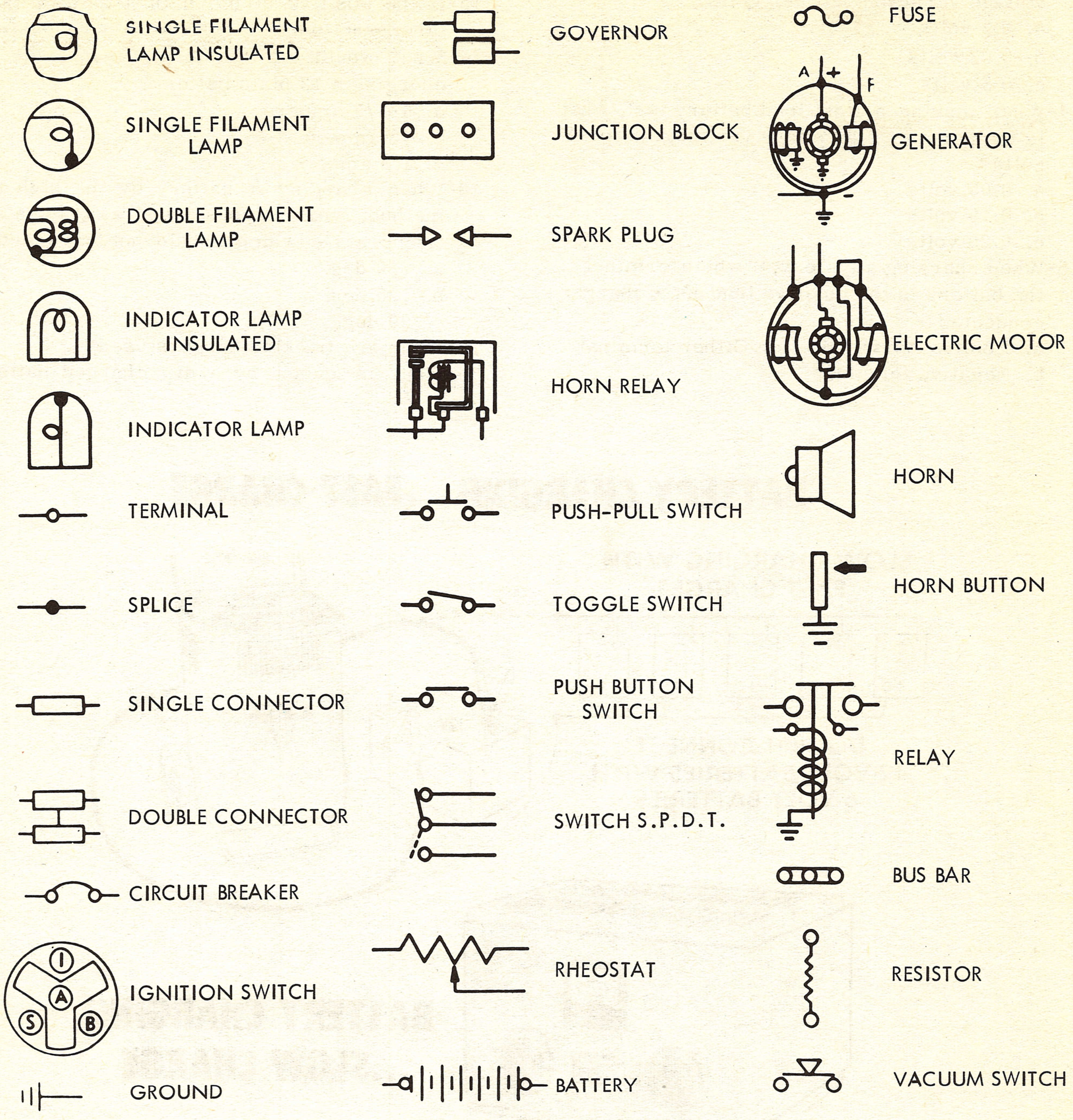
3-What factors control the amount of current that can be produced by a single cell of a storage battery?

4-What is used to fill the positive plate grids of a storage battery?
  a. Lead peroxide
  b. Sponge lead
  c. Antimony oxide
  d. Sulphuric acid

5-Name three materials used to make plate separators in a storage battery.

6-What is the specific gravity of the electrolyte used to fill lead storage batteries?
  a. 1.290
  b. 1.920
  c. 1.450

7-What instrument is used to measure the specific gravity of a liquid?


SINGLE FILAMENT LAMP INSULATED
SINGLE FILAMENT LAMP
DOUBLE FILAMENT LAMP
INDICATOR LAMP INSULATED
INDICATOR LAMP
TERMINAL
SPLICE
SINGLE CONNECTOR
DOUBLE CONNECTOR
CIRCUIT BREAKER
I
A
S
B
IGNITION SWITCH
GROUND
GOVERNOR
JUNCTION BLOCK
SPARK PLUG
HORN RELAY
PUSH-PULL SWITCH
TOGGLE SWITCH
PUSH BUTTON SWITCH
SWITCH S.P.D.T.
RHEOSTAT
BATTERY
FUSE
A
+
F
GENERATOR
-
ELECTRIC MOTOR
HORN
HORN BUTTON
RELAY
BUS BAR
RESISTOR
VACUUM SWITCH

36-48. Typical symbols used in electrical wiring diagrams.

a. Hygrometer
b. Barometer
c. Hydrometer
d. Gravometer

8-The specific gravity reading of a storage battery is 1.290 at 90 deg. Fahr. What is the correct specific gravity?

9-While a storage battery is discharging, what chemicals are formed from the lead peroxide and the sulphuric acid?

10-On a partly charged battery, the voltage regulator setting is increased from 7.2 to 7.5 volts. How does that affect the charging current?
a. Has no affect on charging current
b. Charging current increases
c. Charging current decreases

11-How many cells in a 12 volt storage battery?

12-As the temperature drops, does a storage battery have more or less cranking power?

13-When making a high rate discharge test of a storage battery, what is the permissible

voltage variation between cells?
a. 0.2 volts
b. 0.02 volts
c. 0.6 volts

14-When making a light load battery test, what is the permissible voltage variation between cells?
a. 0.05 volts
b. 0.15 volts
c. 0.20 volts

15-When charging a battery, to which terminal of the battery is the positive lead of the charger connected?
a. Positive terminal
b. Negative terminal
c. Either terminal

16-If the positive terminal of a battery is not otherwise marked, how can it be recognized?

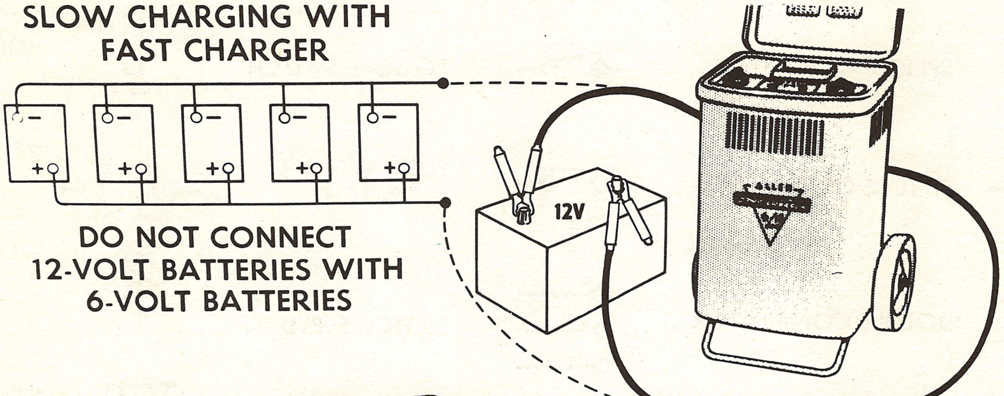
17-What would be the normal safe rate for charging a 13 plate battery?
a. 6-1/2 ampere
b. 13 ampere
c. 1.3 ampere

18-When charging a battery by the high rate method, what is considered as being a safe temperature which should not be exceeded?
a. 212 deg.
b. 125 deg.
c. 80 deg.

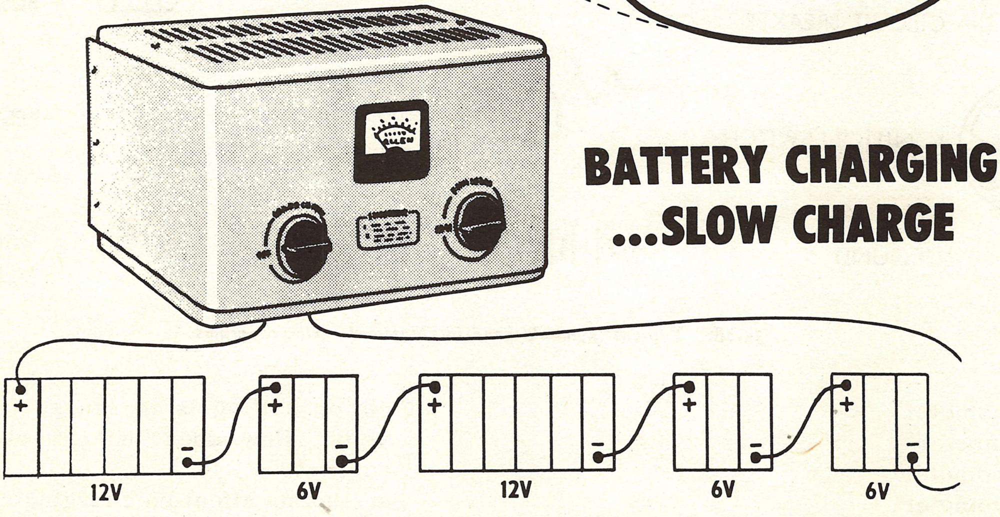
19-When are trickle chargers used?

20-What is meant by a dry charged battery?

BATTERY CHARGING ...FAST CHARGE


SLOW CHARGING WITH FAST CHARGER
12V
DO NOT CONNECT 12-VOLT BATTERIES WITH 6-VOLT BATTERIES

BATTERY CHARGING ...SLOW CHARGE

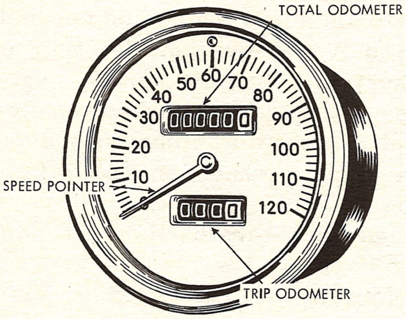

12V
6V
12V
6V
6V

6 AND 12-VOLT BATTERIES MAY BE PLACED IN SERIES ON THE SAME LINE WITH A SLOW CHARGER

SPEEDOMETERS

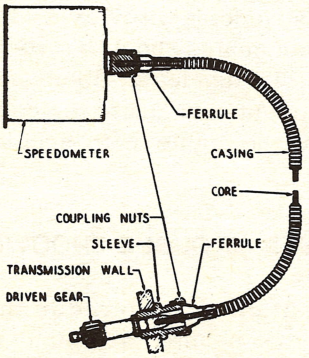
The speedometer used on an automotive vehicle indicates the speed of the vehicle and also records the distance traveled.

A speedometer as shown in Fig. 36-52, is driven by a flexible shaft, Fig. 36-53, connected with gearing within the transmission where it is protected from dirt and receives ample lubrication.


TOTAL ODOMETER
10
20
30
40
50
60
70
80
90
100
110
120
000000
0000
SPEED POINTER
TRIP ODOMETER

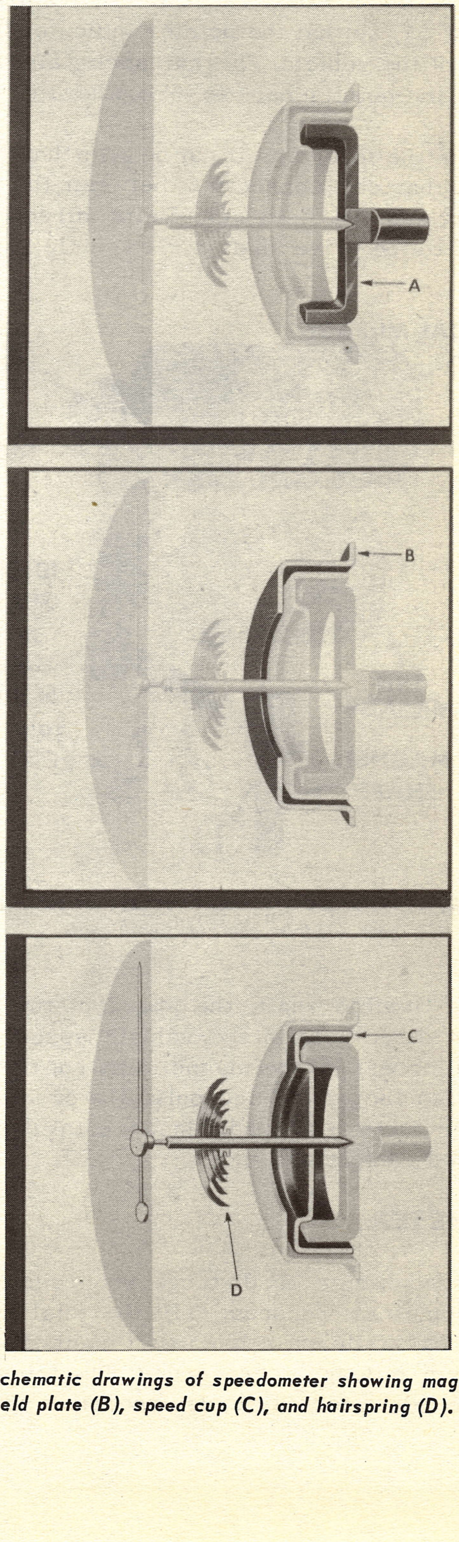
36-52. *Typical speedometer with both total and trip odometer.*

To measure the speed of the vehicle and register the distance traveled requires a separate series of parts. To measure the speed, a magnet, speedcup, field cup, spindle, hairspring and pointer are used. The odometer or distance recorder utilizes a series of gears connected to the odometer dials or disks which carry on their edges the mileage figures.


FERRULE
SPEEDOMETER
CASING
CORE
COUPLING NUTS
SLEEVE
FERRULE
TRANSMISSION WALL
DRIVEN GEAR

36-53. *Speedometer with drive cable connected to transmission.*

The speed indicating portion of the speedometer operates on the magnetic principle. In the head of the speedometer, the drive cable attaches directly to a permanent magnet (A), Fig. 36-54, which consequently rotates at the

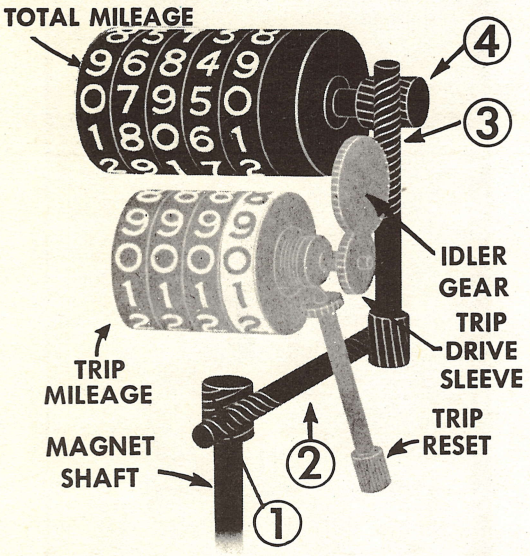


36-54. *Schematic drawings of speedometer showing magnet (A), field plate (B), speed cup (C), and hairspring (D).*

same speed as the flexible drive cable. Floating on bearings, between the field plate (B) and the rotating magnet (A), Fig. 36-54, is a non-magnetic precision balanced speedcup (C). The rotating magnet produces a rotating magnetic field which produces a definite pull on the speedcup. A pointer or indicator is attached to the speedcup which indicates the speed on the dial of the instrument.

The amount of magnetic pull exerted by the rotating magnet on the speedcup is controlled by adjusting a finely calibrated hairspring (D), Fig. 36-54, so that the pointer indicates the true speed of the vehicle. This hairspring also serves to pull the pointer back to zero, when the vehicle stops.

From the foregoing it can be seen that there is no mechanical connection between the driven magnet and the field cup. Being directly connected to the drive shaft of the vehicle by means of the flexible shaft, the speed of the magnet varies directly with the vehicle speed. As the speed increases, the magnetic pull on the speedcup also increases and pulls the speedcup and pointer further around, thus indicating the increased vehicle speed.



36-55. Showing total and trip odometers. (1) first gear. (2) second gear. (3) third gear. (4) fourth gear.

ODOMETER

The odometer or distance recorder of some speedometers records only the total distance traveled, while on other instruments both total and trip mileage is recorded. The trip portion of the odometer is so designed that it can be turned to zero by means of a manual adjustment.

The total odometer, Fig. 36-55, is driven through a series of gears originating at a worm gear cut on the magnet shaft. This assembly, known as the first worm and magnet, drives an intermediate "second gear" and the third gear which is connected to the fourth gear turns the odometer through several cogs in the dummy wheel. The total odometer incorporates five figure wheels and is so constructed and geared that as any one wheel finishes a complete revolution, it turns the next figure wheel to the left one-tenth revolution.

The trip odometer, Fig. 36-55, is also driven by the same gears, then through an idler gear attached to the main frame and connecting with the trip drive sleeve on the trip odometer shaft. The trip odometer usually incorporates four figure wheels and is so constructed that as any wheel finishes a complete revolution, it turns the figure wheel on the left one-tenth revolution.

While speedometers of different manufacturers differ in detail, they are all designed so that 1001 revolutions of the flexible drive cable will register one mile on the odometer and 1001 r.p.m. of the cable will indicate a speed of 60 m.p.h. The gears in the transmission are designed for that particular vehicle and take into consideration the tire size and rear axle ratio.

CARE OF SPEEDOMETERS

Speedometers require very little attention; however, some instruments are provided with a lubrication felt or wick in the speedometer head. In such cases the wick should be saturated with special speedometer oil every 10,000 miles.

Speedometer cables should be lubricated every 10,000 miles. To lubricate, disconnect the cable at the instrument and draw the cable from the casing. Coat the cable with special lubricant and replace.

SPEEDOMETER TROUBLE SHOOTING

Most difficulties encountered in the operation of speedometers usually originate in the drive cable. The cable may be broken, kinked or in need of lubrication. The trouble shooting chart, Fig. 36-56, lists the usual troubles, together with their causes and remedies.

In addition to the conditions listed in Fig. 36-56, if the speedometer pointer wavers or fluctuates, the difficulty may be caused by either a kinked cable or the trouble may be in the speedometer head. The kinked cable rubs in its

TROUBLE	CAUSE	REMEDY
Pointer fluctuates or wavers.	Broken, worn or dirty upper or lower jewel.	Replace or clean jewels.
	Excessive end play in magnet shaft.	Reflare collar on end of magnet shaft.
	Dirt, grease or foreign matter on magnet and/or speedcup.	Clean magnet and speedcup with cloth. Care must be taken to prevent damage to speedcup and hairspring.
	Speedcup shaft rusted or corroded at jewels.	Clean ends of shaft. If too badly rusted or corroded, replace speedcup.
	Worn magnet shaft sleeve on frame.	Replace main frame on magnet assembly as required.
	Lower jewel bracket out of line.	Line up lower jewel bracket with main frame. If bracket is bent, replace.
	Bent speedcup shaft.	Discard and replace.
Pointer does not return to zero.	Weak, broken or improperly adjusted hairspring.	Replace or adjust hairspring, or replace hairspring and speedcup assembly.
	Upper jewel too tight.	Adjust upper jewel so there is very slight play in speedcup shaft.
	Dirt or grease in mechanism.	Disassemble and clean.
	Pointer improperly set.	Reset pointer at zero mark on face dial.
	Weak magnet.	Replace magnet and hairspring.
Incorrect speed indication.	Dirt or grease in mechanism.	Disassemble and clean.
	Out of calibration.	Adjust or replace hairspring.
Instrument reads correctly on only one-half scale.	Hairspring coils touching.	True hairspring with tweezers. Coils should not touch at any point.
	Speedcup out of balance.	Balance or replace speedcup.
Excessive noise.	Too much end play or worn gears on magnet shaft.	Flare magnet shaft or replace gears.
Odometer does not operate.	Stripped gear on magnet shaft.	Replace magnet.
	Excessive end play in first cross gear.	Adjust to proper end play.
	First and second cross gears stripped or worn.	Replace gears.
	Odometer bound up.	Replace complete odometer assembly. Do not attempt to repair.
	Odometer intermediate gear turning on shaft.	Restake gear on shaft.
Odometer does not record correctly.	Wrong speedometer gears.	Replace with correct gears. (Gears used in speedometers reading in kilos are approximately one-third faster than gears used in speedometers reading in miles.)

36-56. List of common speedometer troubles, together with their causes and remedies.

housing and winds up, slowing down the pointer. The cable then unwinds suddenly and the pointer jumps.

To check a cable for kinks, remove it from its casing and lay it on a flat surface. Then twist or rotate one end of the cable with the fingers. If the cable turns over smoothly it is not kinked. But if part of the cable turns over suddenly as it is twisted, it is kinked and should be replaced. Another method of testing a cable for kinks is to hold each end in your hands with the cable looped down in front of you. Then slowly rotate the ends of the cable between your fingers. If it is kinked, the cable will "flop" and not turn smoothly.

If the cable appears to be in good condition, a rough test can be made to determine if the difficulty is in the speedometer head. Secure a short piece of speedometer cable (3 to 4 in. long) with a tip to fit the speedometer. Insert the short cable in the speedometer and spin the cable between your fingers. If there is any tendency to bind, or if there is any roughness felt, the speedometer is defective and should be repaired or replaced.

Sometimes during cold weather a speedometer will become noisy and the pointer may indicate maximum or higher than actual speed. This is caused by excessive friction in the speedcup bearings. In such cases the speedometer should be overhauled or replaced.

If the speedometer does not indicate any speed or mileage, the usual cause is a broken cable. However, in some cases, it may be caused by a defective speedometer.

When the speedometer pointer does not return to zero, or when the speedometer shows speed but no change in mileage, or mileage and no speed, the difficulty is in the instrument.

Occasionally both speed and mileage readings will be too high or too low. In such cases, the tires should be checked for size and the speedometer gears in the transmission should be examined to make sure they are of the correct ratio for that particular vehicle.

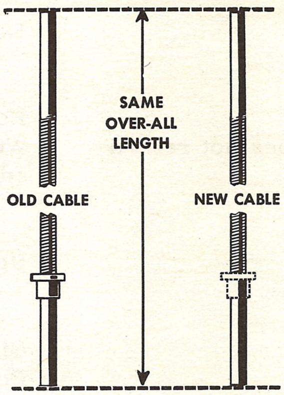
SPEEDOMETER CABLE REPLACEMENT

Speedometer cables break as the result of age, lack of lubrication, or because the cable casing has been installed so that it has sharp bends which results in excessive bending and flexing of the cable as it is revolved. In such cases the clamps holding the casing in position should be relocated so as to eliminate the sharp bends. When such bends are found in the casing, it may be necessary to replace same, which because of rough spots in the interior of the casing would tend to cause binding, friction and rapid wear of the cable.

Another cause of frequent breakage of the speedometer cable is excessive friction in the speedometer head. The test for such a condition has been described in a previous paragraph.

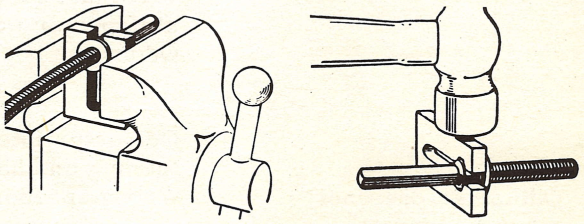
Replacement cables can be secured with both end tips in place or in kit form. In the latter case it is necessary to cut the cable to the desired length and attach the tip in place.

If a "tailor made" cable is to be installed, the casing should be disconnected from the speedometer head, and the old cable withdrawn from the casing. If the old cable is broken, it will be necessary to also disconnect the casing at the transmission end so that the other section of the broken cable can be removed.



36-57. New cable must have the same overall length as the original cable.

After withdrawing the old cable, spread a thin coat of speedometer cable grease evenly over the lower two-thirds of the new cable. Do not apply grease to the entire cable as that would result in the lubricant working up the cable and into the speedometer head and causing damage. After applying the lubricant to the cable, insert the cable into the upper end of the casing, lower end first. This will spread the grease evenly over the entire length of the cable.



36-58. Flexible speedometer cable can be staked to the tip by using the staking tool as shown.

Connect the upper end of the casing to the speedometer case, making sure that the cable tip engages correctly in the speedometer drive member. Tighten the ferrule nut. Then twist the lower end of the cable with your fingers to make sure it turns freely. A sharp twist of the cable should cause the speedometer needle to register. Finally, connect the lower end of the casing to the transmission, making sure that the cable engages in the speedometer driven gear.

When a cable kit is being used as a replacement, the procedure is as follows: First cut the new cable the same length as that of the old cable, Fig. 36-57. Be sure to include the length of the tip which is to be staked on the cut end of the cable. Fit the new tip of correct shape to the cut end of the cable. Place the tip in the staking tool and squeeze the tool in the jaws of a vise or strike it a sharp blow with a hammer, Fig. 36-58. Finally check the new cable for length against the original cable so as to be sure that the overall length is the same.

QUIZ - SPEEDOMETERS

1-How is the modern speedometer driven?

2-The modern speedometer shows only the speed of the vehicle.
  a. True
  b. False

3-On what principle does the speed indicating portion of the speedometer operate?
  a. Electronic
  b. Mechanical
  c. Magnetic
  d. Electrical

4-What means is used to control the pull on the speed cup?
  a. Hair spring
  b. Mechanical brake
  c. Magnetic brake

5-Describe the operation of a speedometer.

6-What does an odometer record?

7-How is the odometer driven?

8-How many revolutions of the drive cable will register one mile on the meter?
  a. 101 revolutions
  b. 1001 revolutions
  c. 3.77 revolutions
  d. 4.01 revolutions

9-Where do most troubles in a speedometer originate?

10-Describe the procedure for checking a speedometer for kinks.

11-Describe a method of checking a speedometer to see if there is any bind present.

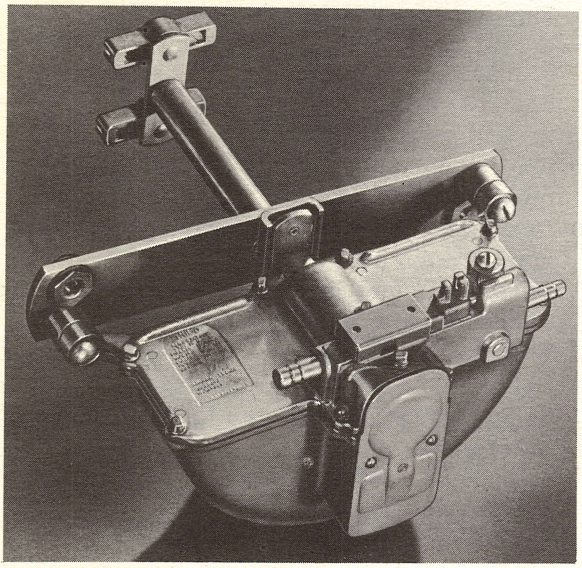
12-What is the usual result of excessive friction in the speed cup bearing during cold weather?
  a. Speedometer indicates higher than normal speed
  b. Speedometer indicates lower than normal speed
  c. Incorrect odometer readings

13-Give four common causes of speedometer cable breakage.

WINDSHIELD WIPERS

VACUUM OPERATED WIPERS

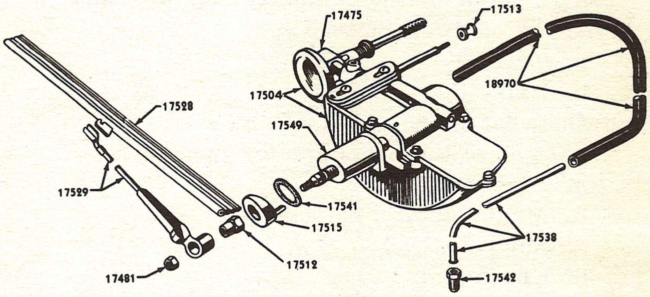
Vacuum operated windshield wipers, Fig. 36-59, depend on the vacuum in the intake manifold for power. The device consists essentially of a piston within a cylinder. By means of valves, controlled by the position of the piston, first one end of the cylinder is connected to the intake manifold and then the other. In that way, the piston is moved back and forth within the cylinder. Movement of the piston causes the operating shaft to oscillate, which in turn swings the windshield wiper blade back and forth across the face of the windshield.



36-59. ***Recent model Trico vacuum windshield wiper motor, with built-in control valve for operating windshield washer.***

As explained in the section on carburetion and fundamentals of engine, intake manifold vacuum is maximum at idling speed and zero at full throttle operation. As a result, vacuum operated windshield wipers will not operate when the carburetor throttle is wide open. To overcome this difficulty, a vacuum pump is incorporated in the fuel pump (see Fuel Pumps) so that there will always be vacuum available for operation of the windshield wiper.

Originally cars were only equipped with a single windshield wiper, Fig. 36-60. This was placed in front of the driver. In order to increase visibility and widen the range of vision, an additional wiper is placed on the opposite side of the windshield. This second wiper blade was at first operated by another wiper motor. More recently, both wiper blades are operated by a single motor with suitable linkage, Fig. 36-61, so that the wiper blades on both right and left sides of the windshield are synchronized.



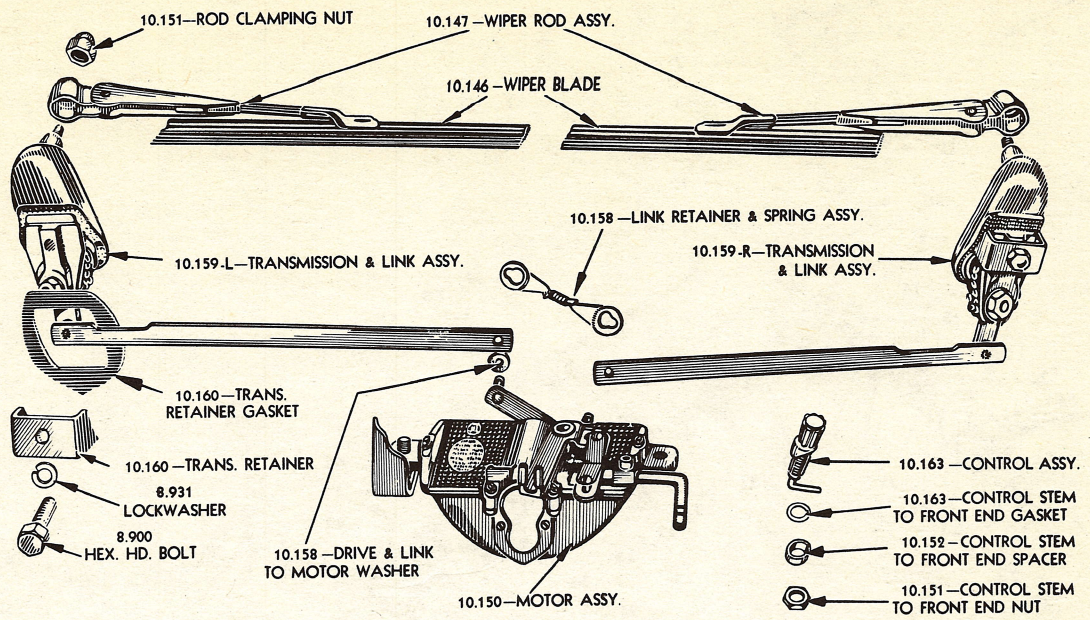
36-60. Vacuum windshield wiper motor. Tubing for connecting to intake manifold is shown at 18970. Windshield wiper arm 17529, and wiper blade 17528.

TROUBLE SHOOTIN ON VACUUM WINDSHIELD WIPERS

Failure of vacuum windshield wipers is usually caused by leaks or stoppage in the vacuum line. Leaks can usually be found by careful examination of the vacuum line and its connections, while stoppage can be located by blowing through the line with compressed air.

If the motor itself is defective, it is usually replaced with a new unit, rather than repaired. Sluggish operation will occasionally be encountered on old units. In such cases improved operation can be secured by disconnecting the vacuum line at the manifold and immersing the line in light machine oil. Then by moving the wiper blade back and forth across the windshield, oil will be drawn into the motor providing lubrication.

On twin windshield wipers, trouble may also be encountered in the transmission and link assemblies. The difficulty is usually the result of wear and in such cases the usual practice is to replace the worn parts. Adjustments are pro-

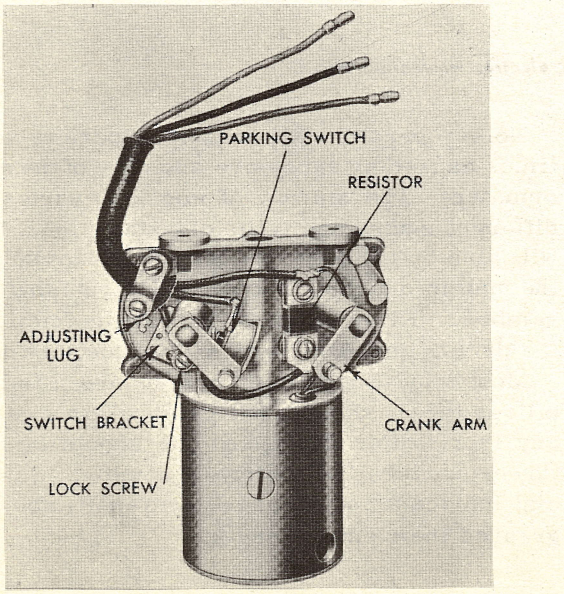

10.151—ROD CLAMPING NUT
10.147—WIPER ROD ASSY.
10.146—WIPER BLADE
10.158—LINK RETAINER & SPRING ASSY.
10.159-L—TRANSMISSION & LINK ASSY.
10.159-R—TRANSMISSION & LINK ASSY.
10.160—TRANS. RETAINER GASKET
10.160—TRANS. RETAINER
8.931 LOCKWASHER
8.900 HEX. HD. BOLT
10.158—DRIVE & LINK TO MOTOR WASHER
10.150—MOTOR ASSY.
10.163—CONTROL ASSY.
10.163—CONTROL STEM TO FRONT END GASKET
10.152—CONTROL STEM TO FRONT END SPACER
10.151—CONTROL STEM TO FRONT END NUT

36-61. Dual windshield wiper, showing motor, transmission and link assembly, wiper rod and wiper blades.

vided on some installations and in such cases, the adjustment should be checked.

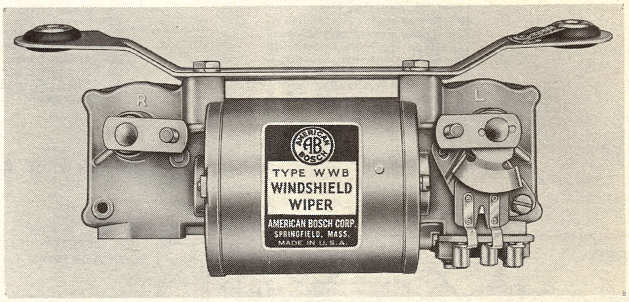
ELECTRIC WINDSHIELD WIPERS

Electric windshield wipers are usually operated by shunt or compound wound motors, Figs. 36-62 and 36-63. Both single and two speed electric wipers are available. An exploded view of an Auto-Lite electric windshield wiper is shown in Fig. 36-64.


PARKING SWITCH
RESISTOR
ADJUSTING LUG
SWITCH BRACKET
CRANK ARM
LOCK SCREW

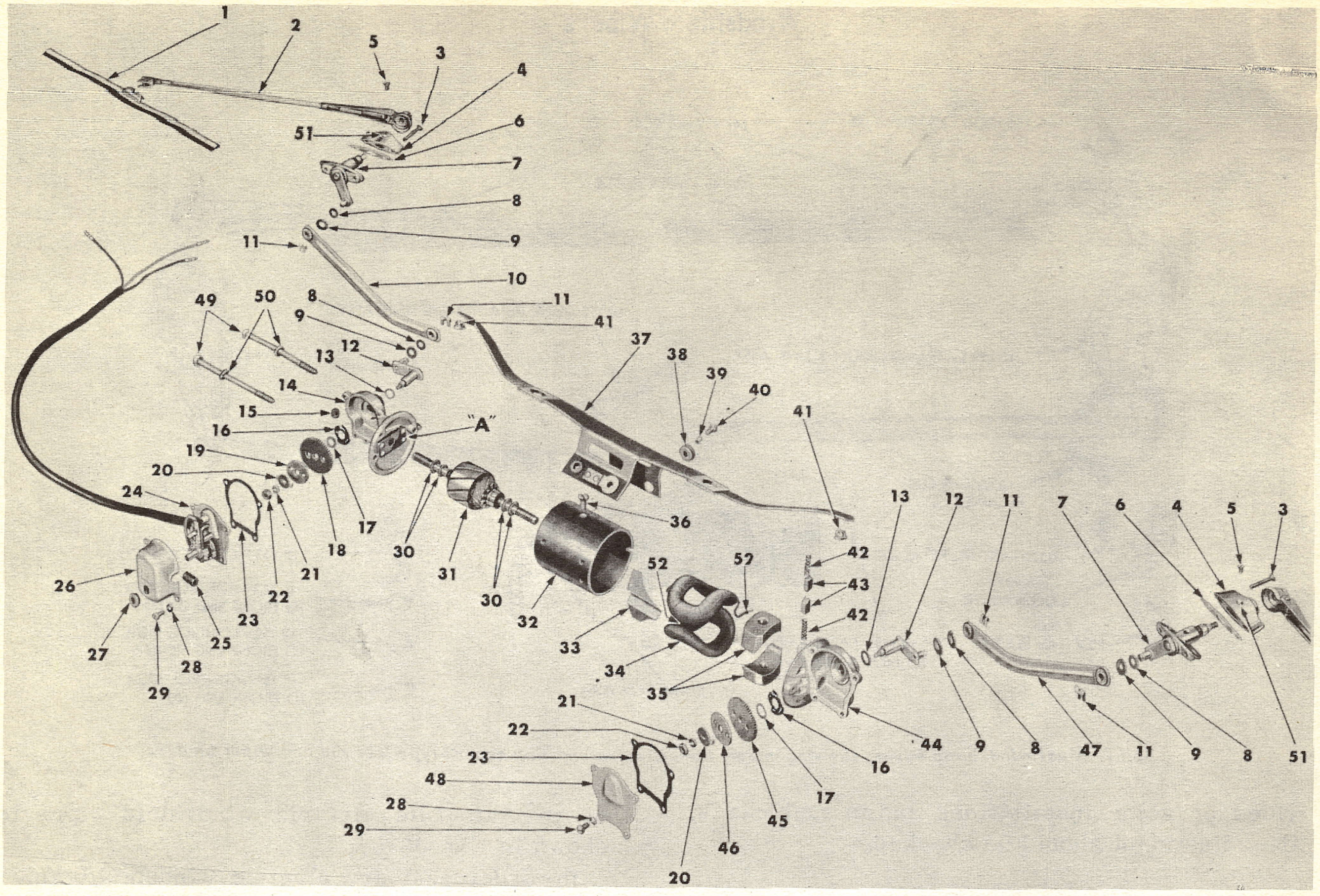
36-62. Auto-Lite windshield wiper motor provided with a parking switch and a special circuit that provides for a fixed parking position. Reciprocating motion is implied by the linkage between the cranks and the wiper arm pivots.

In order that any electric windshield wiper may operate satisfactorily, it is essential that the motor, linkage and drive pivots operate freely, otherwise the operation of the assembly may be noisy or complete failure will result.


R
L
AMERICAN AB BOSCH
TYPE WWB
WINDSHIELD
WIPER
AMERICAN BOSCH CORP.
SPRINGFIELD, MASS.
MADE IN U.S.A.

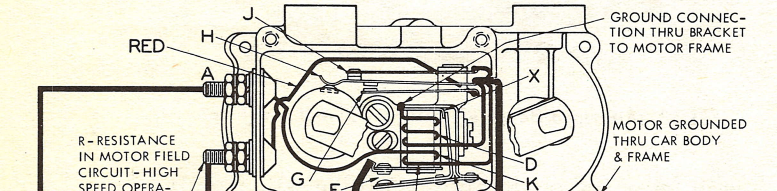
36-63. American Bosch electric windshield wiper motor.

Fig. 36-65 illustrates the wiring diagram of an Auto-Lite double crank arm wiper. Two speeds are provided. At low speed the motor has full field current, while for high speed a resistance is inserted in the field circuit. The control switch is provided with three positions: "Off," "Low Speed," and "High Speed." When the dash control switch is turned to the "Off" position, the motor will continue to operate until a cam on the crank arm strikes the switch button, opening the circuit. Parking position of the blade is adjusted by moving the bracket on which the parking switch is mounted.



1—Wiper blade
2—Wiper arm
3—Pivot cover screw
4—Pivot cover
5—Lubricating hole screw
6—Cover gasket
7—Wiper linkage pivot
8—Link thrust washer
9—Felt washer (lubricating)
10—Link assembly-left
11—Link retaining lock
12—Wiper motor crank arm
13—Crank arm thrust washer
14—Head assembly-drive end
15—Wiring harness grommet
16—Spring tension washer
17—Gear thrust washer
18—Worm follower gear-left
19—Worm follower gear plate (with ramp)
20—Worm follower gear key
21—Gear retaining lock washer
22—Gear retaining nut
23—Gear housing gasket
24—Parking switch assembly
25—Field coil lead insulator
"A" Thrust bridge
26—Parking switch cover
27—Parking switch cover grommet
28—Lock waser
29—Cover screw
30—Armature thrust washers
31—Armature assembly
32—Motor frame
33—Insulation strip
34—Field coil assembly
35—Pole shoes
36—Pole shoe screw
37—Motor mounting bracket
38—Motor insulator grommet
39—Insulator grommet sleeve
40—Motor mounting screw
41—Pivot mounting clip
42—Brush spring
43—Brush assembly
44—Head assembly-commutator end
45—Worm follower gear-right
46—Worm follower gear plate-plain
47—Link assembly-right
48—Gear housing cover
49—Thru bolt
50—Thru bolt lock washer
51—Pivot lubricating hole
52—Field coil leads

36-64. Exploded view of Auto-Lite electric windshield wiper.


J
H
RED
A
GROUND CONNECTION THRU BRACKET TO MOTOR FRAME
X
MOTOR GROUNDED THRU CAR BODY & FRAME
R-RESISTANCE IN MOTOR FIELD CIRCUIT-HIGH SPEED OPERATION ONLY
G
D
K
E
Z
B
BLACK
Y
WHITE
NOTE-SWITCH CONTACT #1 GROUNDED THRU CAR BODY & FRAME
F
R
8
7
6
B
1
CONNECTION GROUNDED TO MOTOR FRAME
C
2
3
4
A
5
T
D
C
BATTERY
OFF - CONTACTS 1&4 - 5&7 CONNECTED
LOW SPEED " 2&5 - 6&8 "
HIGH SPEED " 3&6 "

36-65. Wiring diagram of Auto-Lite type E. W. B. electric windshield wiper.

Noisy operation of electric wipers is sometimes caused by excessive end play of the motor armature. The amount of end play varies with different makes and types of installations. Noise will also be caused by incorrect relation between the motor and the linkage and pivot shaft assemblies. Elimination of excessive friction in the driving mechanism should reduce such noise.

Most windshield wiper motors are fitted with oilless type bushings and therefore do not require any lubrication. The gear box should be filled three-quarters full, before assembly, with special lubricant and all crank arm shafts should be greased their entire length.

ELECTRIC WIPER TROUBLE SHOOTING CHART

Condition	Possible Cause	Remedy
Wiper inoperative	No current at wiper	Check circuit and wiring
	Defective dash switch	Check dash switch mounting
	Wiper unit latching mechanism binding	Check latching mechanism, making sure it operates freely
	Defective relay control	Check relay control
	Drive shaft seized	Free up shaft or replace parts
Wiper will not shut off	Wiper latching mechanism binding	Free up latching mechanism
	Relay control switch defective	Check relay control
	Relay control coil grounded	Eliminate ground
	Drive pawl tab broken	Replace drive pawl
Excessive speed in high speed range but operates normally in low	Resistor on wiper terminal board open	Replace terminal board assembly
Wiper operates in high speed only	Defective dash switch	Check switch for loose mounting and connections
	Circuit between dash switch and wiper unit open	Check circuit
	Open shunt field on motor	Check circuit
Wiper operates in low speed only	Defective dash switch	Check switch and connections
	Circuit between switch and wiper terminal grounded	Check circuit for grounds
Blades do not park	Defective relay switch	Replace switch assembly
Intermittent operation	Weak circuit breaker	Replace motor case and brush assembly
	Armature end play too tight	Adjust end play
Washer inoperative	Defective hose	Replace hose
	Defective dash switch	Replace switch
	Defective relay coil	Replace relay coil

QUIZ - WINDSHIELD WIPERS

1-What is the major source of vacuum used to operate a windshield wiper?

2-Describe the basic operation of a vacuum windshield wiper.

3-How are two wiper blades operated when there is only one wiper motor?
- a. By means of suitable gearing
- b. By means of linkage
- c. Magnetically

4-What is the most frequent cause of failure of the vacuum type windshield wiper?
- a. Leaks or stoppage in vacuum line
- b. Excessive friction
- c. Stripped gears

5-Describe a method of overcoming sluggish operation of a vacuum type windshield wiper.

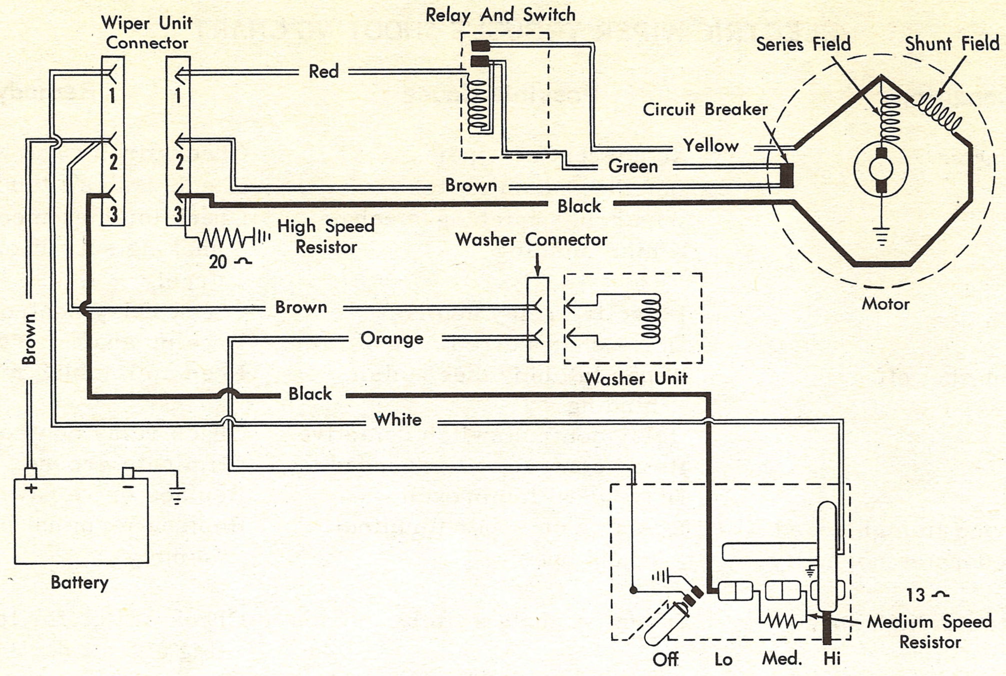
6-What type electric motors are usually used to operate electric windshield wipers.

7-What means are used to control the speed of the electric windshield wiper motor?

8-If armature of wiper motor has excessive end play, what is the usual result?
- a. Noisy operation
- b. Motor speed will increase
- c. Motor will fail to operate

9-Do windshield wiper motors usually require lubrication?

a. Yes b. No


Wiper Unit Connector
1
2
3
1
2
3
Relay And Switch
Red
Series Field
Shunt Field
Circuit Breaker
Yellow
Green
Brown
Black
High Speed Resistor
20 Ω
Washer Connector
Motor
Brown
Orange
Washer Unit
Brown
Black
White
+
−
Battery
13 Ω
Medium Speed Resistor
Off
Lo
Med.
Hi

36-66. Wiring diagram of three-speed windshield wiper including windshield washer pump.

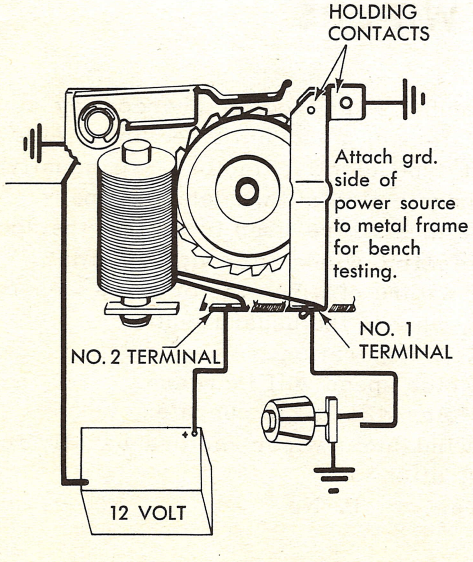
WINDSHIELD WASHERS

Some types of electric windshield wipers also include windshield washer pumps. A wiring diagram of a modern three-speed windshield wiper, including the windshield washer pump, is shown in Fig. 36-66. This shows the circuit for low-speed operation of the wiper blade. It will be noted that the operation of the switch will cut in or cut out resistance to control the speed of the electric motor. This motor is of the series shunt type.

The complete system consists of a wiper unit which contains the 12 v.d.c. motor, a gear box section, a relay control, and a windshield washer pump. The unit drives two wiper transmission link arms, that connect the wiper unit assembly to the two individual wiper transmissions.

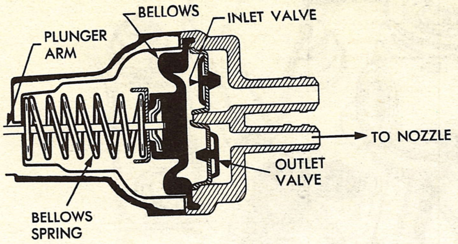
The wipers and washers are controlled by a three-way switch, located on the instrument panel. Some installations have single speed, and others two speed wipers. The washers are activated by a button integral with the switch. By depressing the washer button, the switch lever is mechanically moved to the "Lo" speed position. The washer relay coil is energized by the current flowing from the No. 2 terminal on the wiper unit connector, to the relay coil, and from there to the ground on the control switch.

The windshield washer, Fig. 36-67 which is designed for use with a single speed wiper,


HOLDING CONTACTS
Attach grd. side of power source to metal frame for bench testing.
NO. 1 TERMINAL
NO. 2 TERMINAL
+
12 VOLT

36-67. Washer Pump Schematic.

uses a bellows type pump, Fig. 36-68 and 36-69. This pump is provided with a three lobe rotor cam, and it consists of a relay pump assembly, valve assembly and related parts assembled in a single unit which attaches directly to the gear box of the electric windshield wiper.

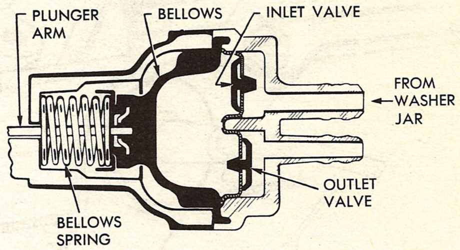


36-68. Washer Bellows---Exhaust.

The washer pump is driven through gears by the wiper motor. Thus when the wiper is operated, the rotor cam of the washer is always turning with the wiper gear. As the rotor cam rotates, it actuates a spring-loaded roller and plunger arm assembly to which a ratchet arm is attached. The lever arm pin extends into the slot of a spring-loaded plunger arm. The spring-loaded plunger arm which is attached to the washer bellows, is held in the retracted position (spring compressed) by an eccentric on the ratchet wheel when the pump is idling.

While the pump is idling, therefore, the lever arm pin can move freely back and forth in the plunger arm slot and no pumping action occurs. The ratchet arm is prevented from rotating the ratchet wheel by a spring which prevents engagement, when the relay coil is not energized.

When the washer button on the instrument panel is pushed in to start the washer, the circuit to the washer pump relay coil is closed to the ground, Fig. 36-67. The relay then pulls the ratchet arm in against the ratchet wheel. The ratchet arm which was previously moving back and forth, now starts to rotate the ratchet wheel. Also a cam allows the contact points to close, which provides a ground circuit after the switch is released. As the ratchet wheel rotates, the eccentric is moved away from the plunger arm tang, releasing the plunger arm for pumping action. The plunger arm being spring loaded now moves in a direction toward the bellows and collapses the bellows, forcing the water in the bellows through the outlet valves in the nozzles, Fig. 36-68. At the same time, the edge of the plunger arm slot moves up tight against the lever arm pin. As the rotor cam is turned, each lobe actuates the lever arm which in turn pulls the plunger arm back compressing the spring. While the plunger arm is being pulled back, water is drawn in through the inlet valve, Fig. 36-69. The cycle is then started over again.



36-69. Washer Bellows---Intake.

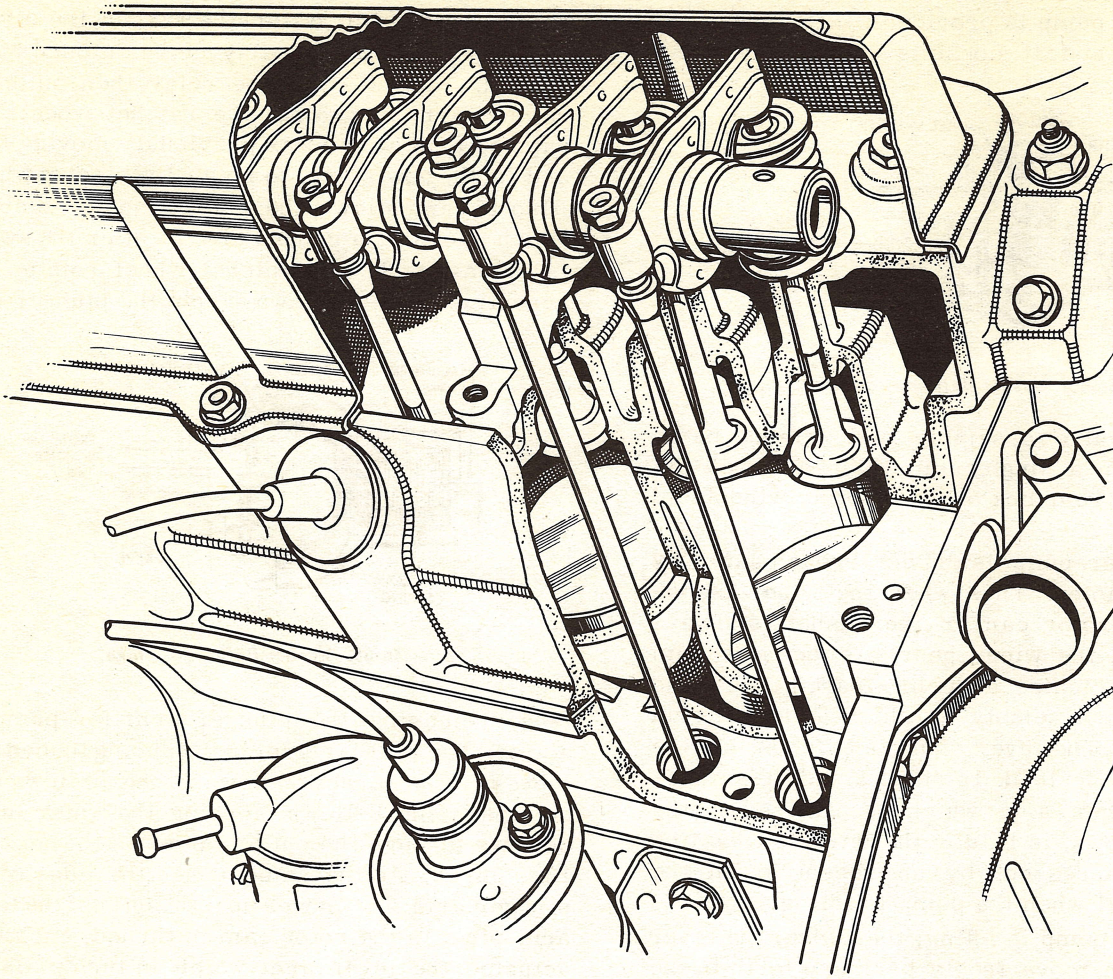
QUIZ - WINDSHIELD WASHERS

1-What type pump is frequently used in the operation of a windshield washer?
  a. Piston type pump
  b. Bellows type pump
  c. Diaphragm type pump

2-Which motor is used to drive the washer motor?
  a. Has individual motor
  b. Is driven by wiper motor

3-Describe the operation of the washer pump.

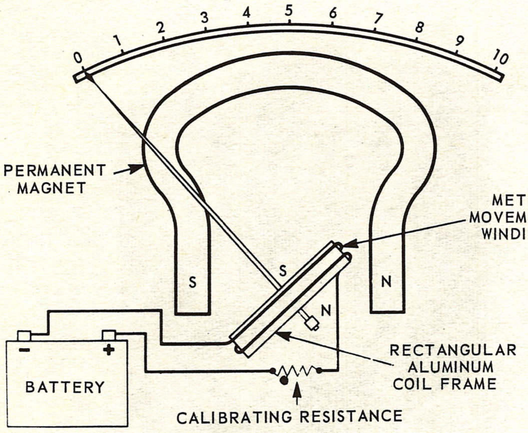
4-List three reasons for an inoperative windshield washer.



Dodge Lancer engine, valve train.

METERS

Diagnosing troubles in electrical systems is one of the most important duties of the automotive electrician. With proper instruments connected in a circuit, he is able to determine where trouble exists, and whether adjustments are needed. In addition, electrical instruments enable him to make adjustments so the electrical equipment conforms to factory specifications. The basic instruments used by the automotive electrician are the ammeter for measuring the current in amperes, and the voltmeter for measuring the voltage or pressure. With the increased use of resistance type high tension ignition wiring, the use of the ohmmeter for measuring resistance, has become important. The oscilloscope is also becoming popular.


0
1
2
3
4
5
6
7
8
9
10
PERMANENT MAGNET
METER MOVEMENT WINDING
S
S
N
N
BATTERY
RECTANGULAR ALUMINUM COIL FRAME
CALIBRATING RESISTANCE

37-1. Schematic drawing of a Voltmeter. Note the calibrating resistance in series with the moving coil.

Meters must of course be accurate, and it must be remembered, that low-priced instruments seldom have the accuracy required. For example, voltmeter scales should be calibrated to 0.1 volt, and ammeters to 0.5 amp. It is not unusual to find instruments with scales indicating such accuracy, but because of design (such as low resistance) the readings will be in error.

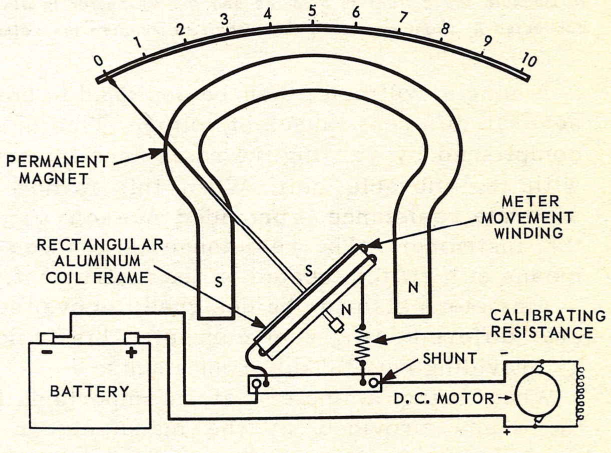
METER DESIGN

Most modern ammeters and voltmeters used in the automotive service field are of the moving coil type, Fig. 37-1 and Fig. 37-2. These instruments consist of a permanent horseshoe or hoop-shaped magnet, and a movable coil. The pole pieces on the ends of the magnet are shaped to provide a uniform magnetic field.

Current flowing through the movable coil reacts with the magnetic field, causing the coil to rotate against the tension of a light spring, which is similar to the hairspring of a watch.

Relative movement of the coil is directly proportional to the current flowing through it. A pointer attached to the coil moves across a calibrated scale, and indicates the amount of current flowing through the coil.

The basic design of ammeters and voltmeters is the same. However, by studying Figs. 37-1 and 37-2, it will be noted that the ammeter is provided with a heavy shunt of low resistance connected across the movable coil. In addition,

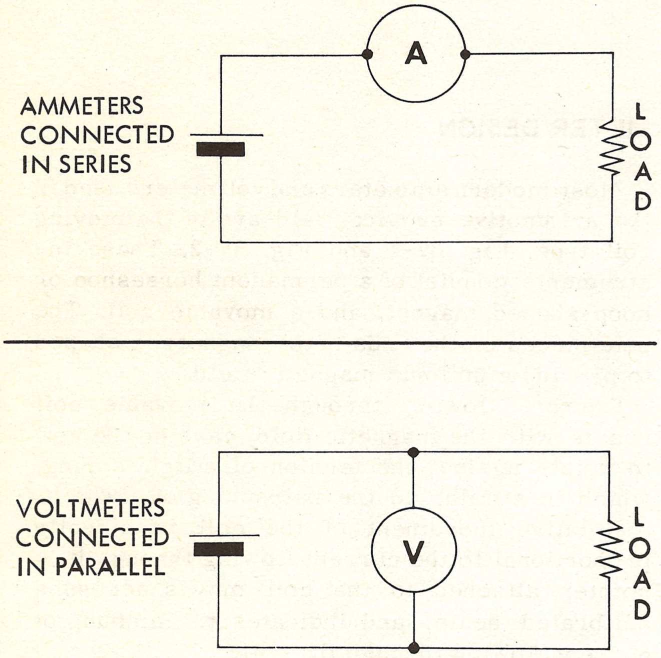

0
1
2
3
4
5
6
7
8
9
10
PERMANENT MAGNET
METER MOVEMENT WINDING
RECTANGULAR ALUMINUM COIL FRAME
S
S
N
N
CALIBRATING RESISTANCE
SHUNT
BATTERY
D. C. MOTOR

37-2. Note that the ammeter has a heavy resistance connected across the moving coil and another resistance connected in series with the moving coil.

there is another resistance connected in series with one end of the shunt and the coil. This resistance is used for calibrating the instrument.

The voltmeter, Fig. 37-1, does not have a resistance shunted across the coil, and has only the calibrating resistance in series with the coil.

Ammeters are always connected in series with the circuit, Fig. 37-3, and voltmeters are always connected across (in parallel) the terminals of the device or circuit. See Fig. 37-3.


A
AMMETERS CONNECTED IN SERIES
LOAD
VOLTMETERS CONNECTED IN PARALLEL
V
LOAD

37-3. Ammeters are always connected in series with the circuit to measure the current in amperes and the Voltmeter is always connected in shunt or across the circuit to measure the voltage.

A single voltmeter can be designed to cover several different ranges of voltage. This is accomplished by varying the resistance in series with the movable coil. When this is done, a separate resistance is provided for each range of the instrument. The resistance is changed by means of a switch located on the instrument.

Ammeters also can be designed to cover several different ranges of current. This is done by providing several different shunts.

When using ammeters it is important that the leads provided by the manufacturer be used. Leads having a different resistance will seriously affect the accuracy of the instrument. This will be particularly noticeable when checking and adjusting voltage regulators.

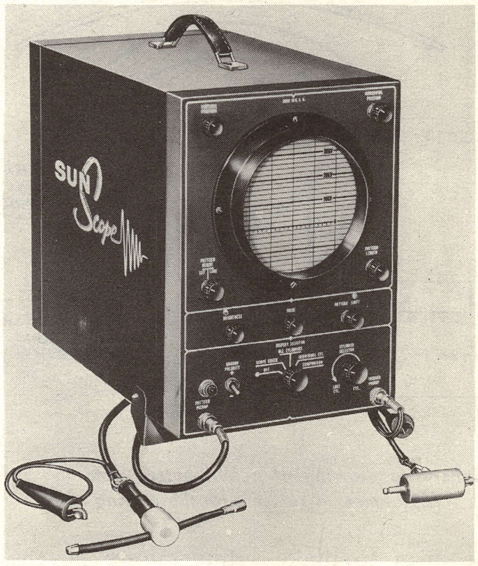
A generally accepted standard for the maximum resistance of an ammeter is 0.1 v. drop across the ammeter terminals of the connected ammeter leads with 10 amp. flowing in the circuit. Therefore the resistance would be .01 ohms.

The resistance of a good voltmeter is usually 100 ohms per volt.

In general, ammeters and voltmeters used for automotive service work should have an accuracy of 1 per cent of full scale deflection. In addition, they should be compensated for changes in temperature.

THE OSCILLOSCOPE

The oscilloscope, Fig. 37-4, is an electronic device which is used to visually observe and measure the instantaneous voltage in an electric circuit. Basically, aside from the vacuum tubes and circuitry required to operate it, the oscilloscope consists of a cathode ray tube, and operates in much the same manner as a television set. The oscilloscope produces a graph-like picture showing voltage values with respect to time. This picture is generally referred to as the pattern or wave form.



37-4. Typical oscilloscope used for checking operation of ignition system.

This pattern or wave form, Fig. 37-5, is produced by the cathode ray or stream of electrons striking the face or screen of the tube, which is coated with a phosphorescent material. When the electrons strike this material, it gives off a brilliant glow, thus making it possible to see or trace the path of the ray as it moves across the screen.

In addition to being able to measure voltage in an electrical circuit, the oscilloscope can be used to determine the polarity of the voltage, which is indicated by the vertical movement of the ray. Thus, when connected to the secondary circuit of an ignition system, the voltage which is normally negative, will appear above the zero reference.

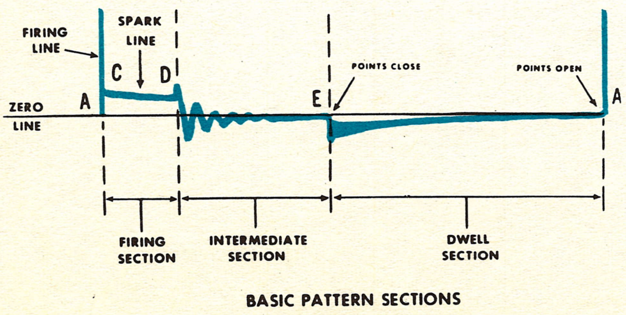
The oscilloscope wave form is controlled by the voltage in the electrical system to which it is connected. Oscilloscopes can also be connected to non-electrical components, by means of special pickups known as transducers. These devices, which convert other forms of energy to electrical impulses, are used to observe engine compression and valve action, and locate noises and vibrations.

As an ignition system analyzer, the oscilloscope can be used to detect the following:

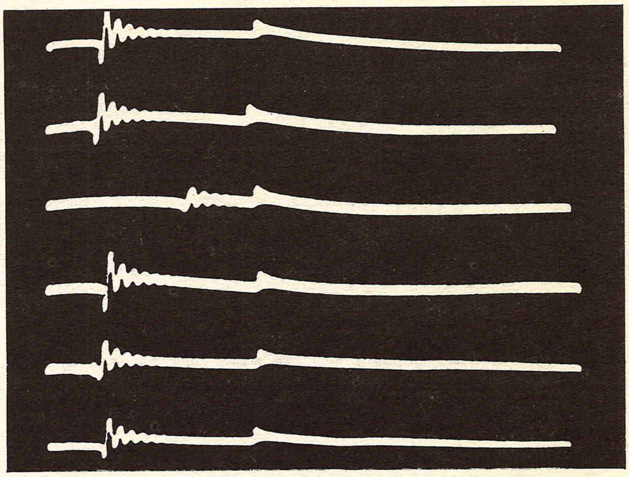
Spark plug firing voltage
Coil action
Condenser action
Breaker point action
Coil available voltage
Reversed coil polarity
Low voltage available
Insulation leakage
Worn spark plug electrodes
Lean air fuel mixtures
Excessive rotor gaps
Breaks in high tension wiring
Excessive primary circuit resistance
Excessive secondary circuit resistance
Poor rotor to cap contact
Fouled spark plugs
Grounded high tension wires
Shorted coils
Shorted condensers
Defective breaker points
Engine load on spark plug voltage
Distributor point dwell

OSCILLOSCOPE WAVE FORM

When studying the oscilloscope wave form or pattern, Fig. 37-5, consider it to be graphs of voltage with respect to time. The vertical displacement from the horizontal zero line (either up or down, depending on the polarity) represents voltage at any instant along the zero line. As oscilloscopes are used mostly in connection with the secondary circuit, as here it is the most informative, the screen is laid out in kilovolts to permit accurate voltage measurements of secondary circuit patterns.



37-5. Basic wave form of ignition system.



37-6. This type oscilloscope places the wave form of each cylinder one above the other, for easy comparison. Note that No. 3 cylinder does not conform with the others. In this case a shorted spark plug is indicated.

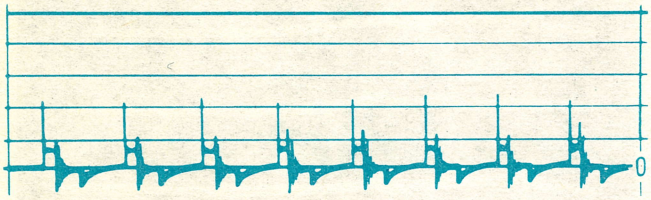
Each part of the wave form represents a specific phase of ignition system operation, and is usually divided into three sections; firing section, intermediate section and dwell section.

The firing section, Fig. 37-5, so called because it is during this period that the actual firing of the spark plug takes place. This section of the wave form is composed of only two lines. The firing line is the vertical line indicating the voltage required to overcome the rotor and spark plug gaps. The spark line is a horizontal line indicating the voltage required to maintain the spark and its duration. Point "A," Fig. 37-5, in the pattern, represents the instant at which the breaker points have opened. The resulting high voltage is indicated by the vertical rise from "A" to "B" in the pattern. The height at point "B" shows the voltage required to fire the plug and rotor gaps. This is often known as the firing or ionization voltage.

After the spark plug fires, there is a noticeable drop in secondary voltage to point "C." As the spark continues to bridge the gap, the spark voltage remains at a fairly constant low value until the spark stops at point "D."

The intermediate section, which immediately follows the firing section, is seen as a series of gradually diminishing oscillations, which just about disappear by the time the dwell section begins. Beginning at point "D," the remaining coil energy dissipates itself as an oscillating current, which gradually dies out as it approaches point "E." The oscillation results from the combined effects of the coil and the condenser, in dissipating this energy.

The dwell section represents the period of time during the ignition cycle in which the breaker points are closed. The dwell section begins at point "E," Fig. 37-5, when the breaker points close. Closing of the points causes a short downward line followed by a series of small rapidly diminishing oscillations. The dwell section continues until the points open at the beginning of the next wave form at point "A."



37-7. *Many oscilloscopes place the wave form of each cylinder one after the other as shown above.*

Some oscilloscopes will show the wave form of each cylinder, one above the other, Fig. 37-6, while others will show the wave form of each cylinder, one after the other, Fig. 37-7.

In Fig. 37-6, all cylinders, except No. 3 are firing correctly. That cylinder has a shorted spark plug as indicated by the fact that the firing voltage (Line "A"-"B") Fig. 37-5, has not built up. Excessive spark plug gaps would be indicated when the firing line is longer than usual. When breaker points are defective or incorrectly gapped, the wave form of the dwell section will not follow the normal pattern. Each difficulty in the ignition circuit will show up in the wave form of the oscilloscope.

The oscilloscope does not replace existing equipment, but is used as an additional aid to trouble shooting. It will show in what area of the ignition system the trouble is occurring; regular metered equipment is then used to pin point the trouble.

QUIZ - ELECTRIC METERS

1-What type magnet is used in a conventional voltmeter?
  a. Electro-magnet
  b. Permanent magnet
2-In a voltmeter, is the calibrating resistance in series or in shunt with the movable coil?
  a. Series
  b. Shunt
3-What is the major difference between a voltmeter and an ammeter?
4-When using an ammeter, how should it be connected in the circuit?
  a. In series
  b. In shunt
5-When a using a voltmeter, how should it be connected in the circuit?
  a. In series
  b. In shunt
6-When using an ammeter, why is it important to always use the leads provided by the manufacturer?
7-What is an oscilloscope used for?
8-What can the wave form shown on an oscilloscope screen tell about the ignition system of an automobile?
9-Name the three sections of the wave form shown by an oscilloscope.
10-If the wave form shown on an oscilloscope screen rises very little above the horizontal zero line, what is indicated?

WHEEL ALIGNMENT

Perhaps what is known as "wheel alignment" could better be known as "steering balance" because correct steering involves a balance of caster and camber with physical forces such as gravity, momentum, friction, centrifugal forces, etc. If the serviceman is to accomplish correct handling of the automobile he must understand WHAT he is doing and WHY.

For this reason he must study the theory of what is required and how to accomplish the proper result. He need not become an automotive engineer but he surely should know the why of what he is trying to do. Otherwise his efforts will be futile and dangerous.

STEERING BALANCE

First of all, it must be understood that the entire matter of steering control is contingent upon the tires maintaining a close and intimate contact with the road surface. This close contact is influenced by the tire tread, tire inflation, wheel balance, weight on the wheel, shock absorber condition, spring action and wheel angularity. This applies to all four wheels and also to the wheels individually. It may be readily understood that unbalanced forces will exist if one front tire has a wide flat tread and the other front tire has a narrow non-skid pattern in contact with the road.

In such cases the tire with the tread worn down flat and smooth would have more rubber in contact with the road, the rolling friction would be greater, the tire would have a tendency to hold back and the car would tend to steer toward the side holding back. The same situation would exist if the tire on one side were under-inflated. Anything that tends to increase the area of tire in contact with the road---such as more weight on one wheel than the other---will increase the rolling resistance on that side and result in the car steering to one side unless some compensating effect is introduced.

If both front wheels are carrying the same weight, are equipped with tires having approximately the same degree of tread wear, are inflated to the same pressure, and properly and equally adjusted for angularity, they would maintain the same contact on a perfectly smooth road surface. There is no such thing as a perfectly smooth road surface so the wheels will move up and down at different times, at different rates of speed, and to differing heights.

This vertical movement will be controlled to a certain extent by the car springs and the shock absorbers. Therefore the condition of the springs and shock absorbers will be a factor in maintaining the contact between the tire and the road without which we cannot control the car.

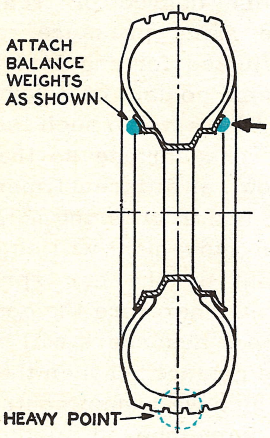
It must be remembered in this connection that each of the four wheels acts as a sort of flywheel to store energy as it acquires momentum. A tire casing, inner tube, rim, wheel and brake drum, rotates as a unit and does possess considerable weight. Anything added to this rotating mass such as double inner tubes or tires with excessively heavy treads will increase the flywheel effect. The lighter the wheel and tire assembly the better it will maintain contact with an uneven road surface, all other factors being equal.

WHEEL BALANCE

Another factor to be considered at this time is the action of centrifugal force. Centrifugal force, as you know, increases as the square of the speed of rotation. For example, a weight of one ounce on the tread of a tire 30 inches in diameter will exert a force of about three pounds at a speed of 30 miles per hour (m.p.h.). Double the speed---60 m.p.h.---and the force becomes quadrupled, amounting to about twelve pounds. At three times the speed---90 m.p.h.---the force becomes twenty-seven pounds. This force is exerted away from the center of rotation and tends to make the wheel bounce. A wheel that is out of balance may not tend to bounce at slow speed but may bounce seriously at higher speed. It is obvious that a bouncing wheel will not hold to the road and should be properly balanced.

Before attempting to balance the wheel assembly, it is important to make sure that the wheel runs true and is ROUND. We have all seen tires with large flat spots worn on the tread. Occasionally we will see a tire that has been retreaded incorrectly and is not round. It is a waste of time and effort to attempt to obtain correct steering with such tires on the front wheels.

A tire casing under the best conditions is not an exact or precise sort of machinery because of its very necessary flexibility. Modern low pressure tires are so flexible that the wheel may roam about WITHIN the tire. As the tire flexes between the wheel and the road the wheel may move up and down, fore and aft, float sidewise and also twist WITHIN the tire itself.

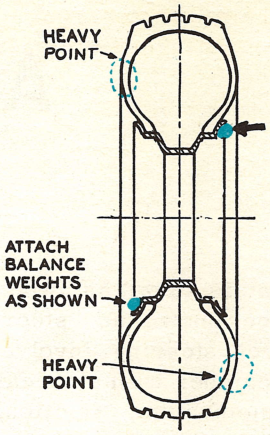


38-1. Static balance can be attained with weights on both sides of the wheel rim.

These actions may take place at any one or all four wheels singly or in combination. For example, the right front wheel might be moving sidewise and twisting within the tire, the left front wheel twisting within the tire, the right rear wheel sinking down on the tire and the left rear wheel almost off the ground. Such a condition could occur while making a left curve on a bumpy road while applying the brakes at high speed. Each tire would under such conditions have a different area of contact with the road.

With all these variables to contend with we cannot work with out-of-round, wobbly or unbalanced wheels and tires. Unbalance may be static or it may be dynamic. Static unbalance lies in the plane of wheel rotation as shown in Fig. 38-1. Dynamic unbalance lies in the zone on either or both sides of the plane of wheel rotation as shown in Fig. 38-2.

Dynamic unbalance in front wheels will cause them to wobble as well as bounce. Rear wheels are not free to wobble but should be kept in static balance to avoid bouncing, which will sometimes interfere with steering action by creating vibration. Wheel and tire assemblies can be balanced both statically and dynamically by the addition of weights placed at the proper location on the rim. Special equipment is required to locate the point or points of unbalance and test the wheels for balance.



38-2. Dynamic balance may require weights spaced around the rim on both sides.

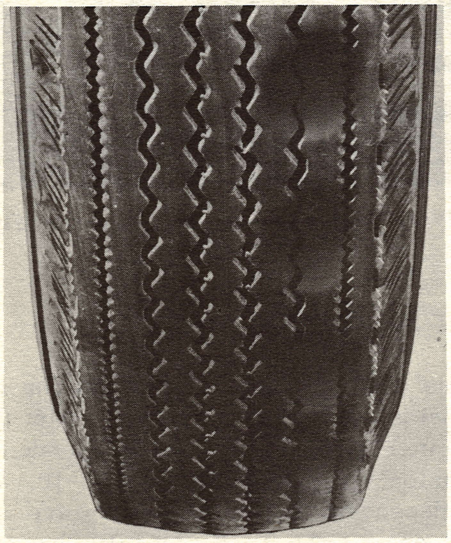
The entire tire, tube, wheel, rim and brake drum assembly should be balanced as a unit. Actually the entire assembly should be checked for balance every time the tire is removed and replaced on the rim or the wheel removed and replaced on the hub. This is seldom done but the balance should be checked at least twice per year as the tires wear unevenly as shown in Fig. 38-3 and may thus get out of balance. It is sometimes almost impossible to balance a wheel where the tire is equipped with a double inner tube because the inside tube will stretch and float around inside the air tube due to the action of centrifugal force on the mass of the rubber.

CAR WEIGHT BALANCE

With the wheels and tires in condition to run true and in balance as previously described, we must now give consideration to the accurate attachment of the wheels to the load to be carried. This also involves balance between front and rear and between each side. While this balance may not mean equal weight front and rear or right and left it does mean a balanced distribution of weight and stress. See Fig. 38-4.

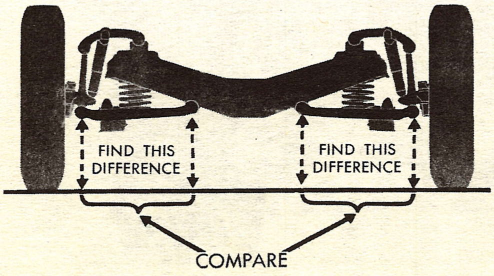
If the wheel spindles are not in proper relation with one another or with the car chassis due to distortion of the frame or for some other reason we obviously cannot obtain properly balanced action. When the front wheels are in the straight ahead position the front wheel spindles should be parallel with the rear wheel spindles. Otherwise the car will want to turn in a circle or the wheel will tend to drag.

Likewise the front wheels should be parallel with the rear wheels so that all four wheels will tend to roll true in a straight line. The front wheels should each be the same distance from the center line of the car and both rear wheels should be the same distance from the center line of the car. The front wheels may have the same tread, a wider tread or a narrower tread than the rear wheels of course, but all wheels should be parallel. See Fig. 38-5.



38-3. *Tire treads wear unevenly sometimes and create a condition of unbalance.*

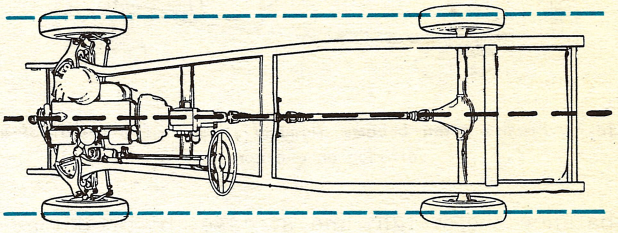
Furthermore the distance from the center of the front wheel to the center of the rear wheel on each side should be the same and the frame must be square. That is, a line drawn through the center of both front or rear spindles must be at a right angle (90 deg.) with the center line of the frame. This is shown in Fig. 38-6.



38-4. *One method of checking for unequal weight distribution from side to side.*

BENT FRAMES

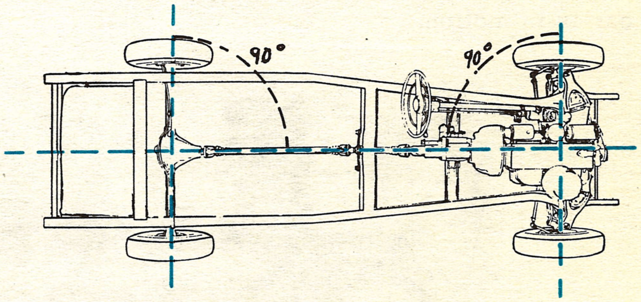
Quite often a car involved in an accident will have a diamond shaped frame; that is one frame side rail is forward of the other. This results in the rear wheels failing to track with the front wheels and the car goes along partly sidewise. See Fig. 38-7.



38-5. *Both front and rear wheels must be parallel to the center line of the automobile.*

Unless the car has been involved in a major wreck the body is seldom removed from the frame and it is difficult to measure directly on the frame to check the above described dimensions. One method often used is to transfer the measurements to a level floor and then check them with a steel tape. The points usually used for checks are shown in Fig. 38-8.

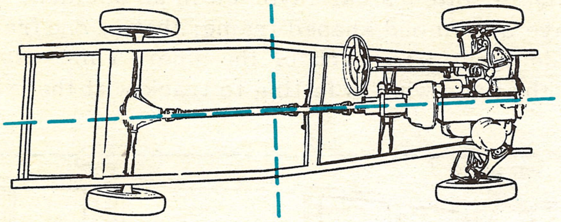
The method of transferring the frame dimensions to the floor is to select several corresponding points on each side of the car and suspend a plumb bob from each one in turn, marking the spot on the floor with chalk. The car is then rolled away and the measurement of the diagonals made. This method is reliable if carefully done but the points of the frame from which the plumb bob is suspended must be carefully selected and the chalk marks accurately placed.



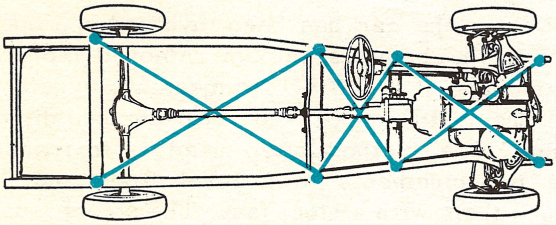
38-6. *All wheel spindles must be at a right angle with the center line in the straight-ahead position.*

If the frame is distorted, it can be straightened with the aid of hydraulic jacks and a series of special bars, clamps and other gear made for the purpose.

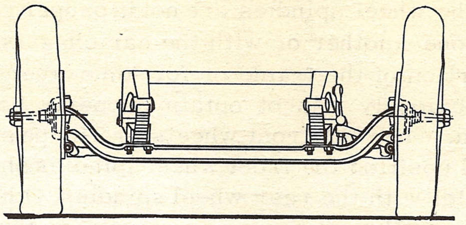
If the frame is square and level and the axles and spindles properly located it is possible to balance the weight and stresses by proper adjustment of caster, camber, king pin inclination and toe-in angles so that the automobile will steer and handle properly. Before we study all these angles and their relation one to the other we shall consider the front wheel suspension system in a general way so that we may better understand what happens when the car is in motion.



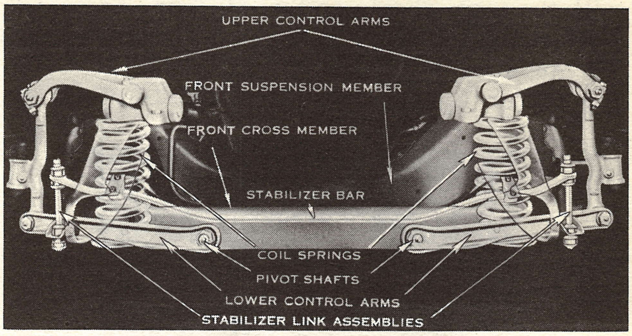
38-7. Frames often become diamond shaped as a result of a collision on one corner.



38-8. Method of measuring frame for squareness.



38-9. Solid axle type front suspension using leaf springs.

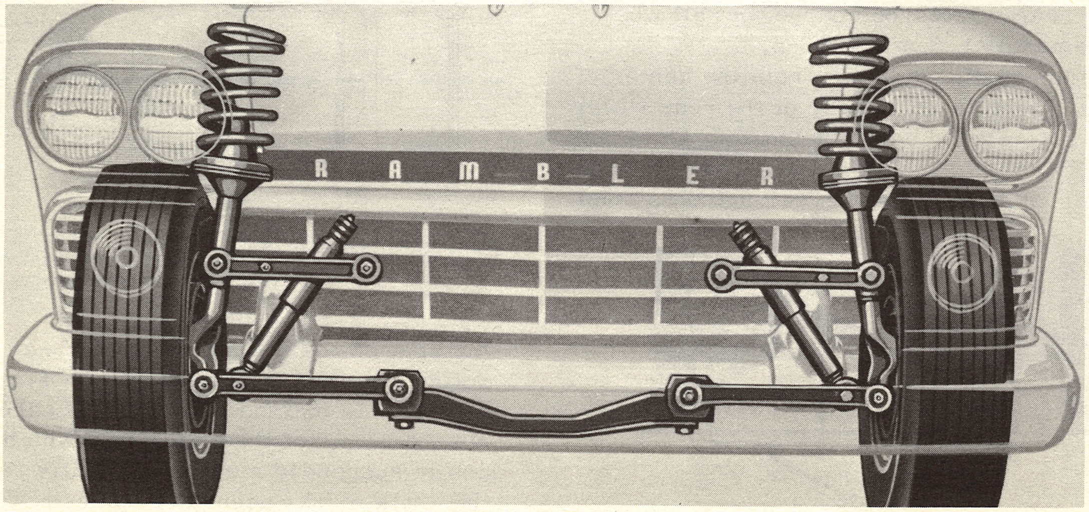

UPPER CONTROL ARMS
FRONT SUSPENSION MEMBER
FRONT CROSS MEMBER
STABILIZER BAR
COIL SPRINGS
PIVOT SHAFTS
LOWER CONTROL ARMS
STABILIZER LINK ASSEMBLIES

38-10. Typical independent front wheel suspension system using coil springs.

FRONT SUSPENSION TYPES

There are two basic classifications of front suspension systems: the solid axle type as shown in Fig. 38-9, and the independent wheel suspension type shown in Fig. 38-10. Most of the independent suspension type are similar to the one shown in Fig. 38-10, but there is wide variation in the type and location of the springs. An example is shown in Fig. 38-11.

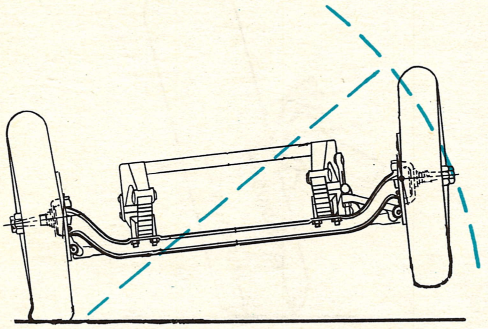
The action of the two types shown in Figs. 38-9 and 38-10 is quite different when the car is moving over the road. When one wheel of a



38-11. In this independent front suspension design, the springs are located on the extended king pin rather than placed between the control arms.

solid axle type rises over a bump the pivot point is the tread of the opposite tire at the road surface. The action of the front wheels is depicted in Fig. 38-12 and shows that one wheel moves in an arc of a circle around the pivot. This changes the wheel angles and the weight balance in several ways which will be further studied later.

When the independently suspended front wheel rises over a bump it does not pivot around the other wheel in the same manner as the solid axle type. It does pivot around two different points as indicated in Fig. 38-13. The difference in these actions is important in the study of wheel alignment because entirely different results occur. This difference must be understood before a successful analysis of steering difficulty can be made.



38-12. A change in the vertical plane of one wheel, on a solid axle vehicle, will change the other wheel.

FRONT WHEEL ANGULARITY

CAMBER

Camber was originally built into front wheels for several reasons (See Fig. 38-14):

A-To place the load more nearly on the heavier inner bearing of the wheel.

B-To avoid reverse camber (wheels leaning inward at the top) as the spindle parts wear.

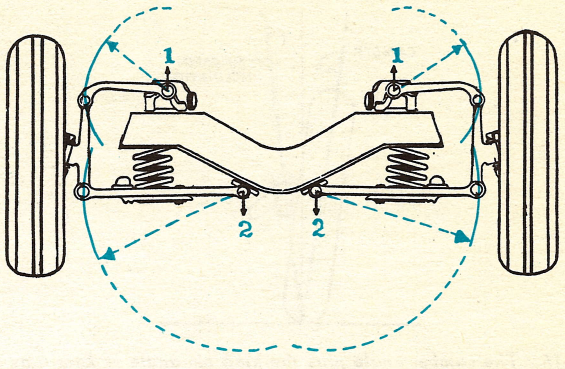
C-Reduce the side thrust on the king pin.

D-To compensate for the center of the wheel rotation plane being outside of the center line of the king pin.

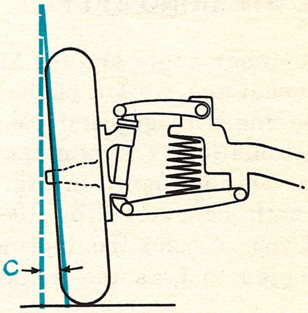
As design and materials have improved the camber angle has been decreased until current cars have very little camber. Some older models have considerable camber.

KING PIN INCLINATION

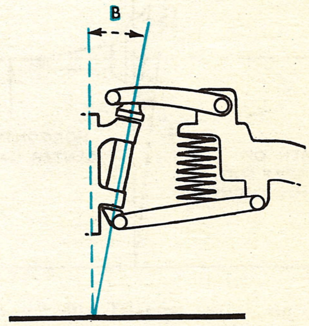
At the same time camber was reduced, king pin inclination was increased. Early king pins were almost vertical but are now inclined inward at the top as shown in Fig. 38-15. This inclination has the effect of placing the turning point at the center of the tire tread instead of inside the wheel. This makes possible more stable steering as the wheel has less tendency to swing around the king pin when it strikes a bump.



38-13. Note that points 1 and 2 are the points about which the control arms pivot as the wheels move up and down. As the arms are of unequal length, there will be some sidewise movement of the upper and lower ends of the spindle arms. While the movement is slight, it does cause the tread to slip sidewise on the road. With proper angle settings this slip is at a minimum.

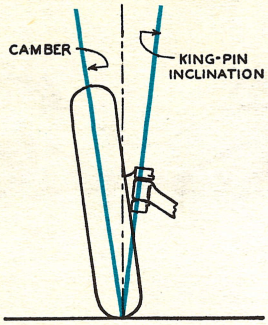


38-14. The camber angle is indicated at C.



38-15. King pin inclination angle is indicated at B.

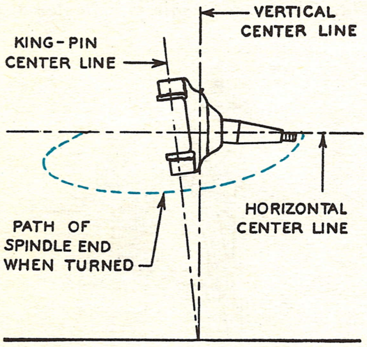
Camber angle and king pin inclination angle are of course closely related and measured together and are known as the included angle. See Fig. 38-16. Camber is built into the wheel spindle by forming the spindle with a downward tilt to provide positive camber. King pin inclination is usually built into the axle ends. While the two angles cooperate and changing one might compensate for the other, it is best to measure them separately in order to determine whether the spindle or the axle is incorrect.



38-16. The camber angle plus the king pin angle is known as the "included angle."

AUTOMATIC STEERING EFFECT

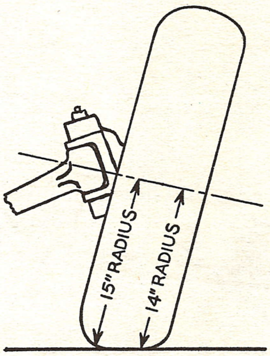
When the camber angle and the king pin angle are both correct the weight of the car helps to hold the steering straight and cause the front wheels to automatically straighten out after a turn is made. This is shown in Fig. 38-17 which traces the path described by the end of the spindle rotating around the inclined king pin. It will be noted that as the spindle turns the end rises and falls. As the car weight is attached to the spindle the car also rises and falls. In other words the car is raised as the front wheels are turned to right or left and is lowered when the wheels are in the straight-ahead position. Thus the weight of the car helps provide automatic steering.



38-17. The king pin is not parallel with the vertical, and the wheel spindle is not parallel with the horizontal. Therefore as the spindle is turned to right or left it drops at the outer end.

The increase of king pin inclination has along with wider and softer tires required more leverage in the steering gear and a slower acting gear. The decrease in camber angle has reduced tire wear on the wider treads. This is because a wheel with considerable camber represents a section of a cone as shown in Fig. 38-18. This results in the tire having several effective rolling diameters. It would tend to roll in a circle, but as it is forced to roll straight the outer or smaller diameter must try to roll faster with the result that the outer part of the tread is ground off by slipping or creeping.

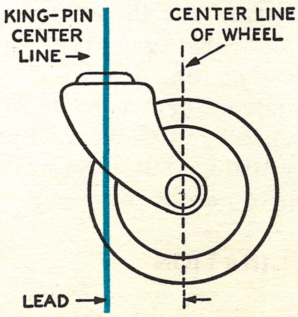
With late models there is very little camber wear but on earlier models with considerable camber there is often pronounced camber wear on the outside of the tread. On solid axle types this kind of wear is aggravated by the frequent changes in camber angle due to the wheels leaning inward and outward when the one wheel pivots around the other as previously described.



38-18. Camber is exaggerated here to indicate that a wide tire becomes a section of a cone and thus has several effective rolling diameters.

CASTER

With the solid type axle it was customary to obtain the automatic steering effect with the aid of caster angle in the king pin. In later models the caster angle has been reduced until it is



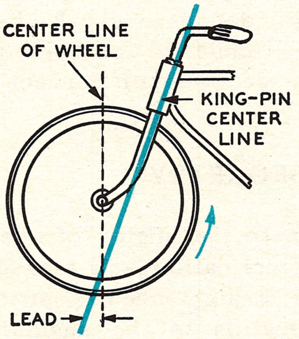
38-19. The lead allows the wheel to trail, or follow.

very slight with none or even slight reverse caster in some independently suspended systems.

Caster is best understood by reference to some other applications of the same principle. Caster is used in rollers under furniture and in bicycle and motorcycle front wheels. It consists of setting up a "lead" by placing the vertical center line of the wheel behind the center line of the pivot or king pin as shown in Fig. 38-19.

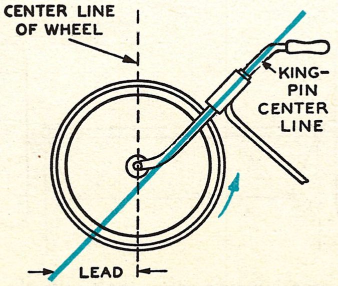
This construction causes the wheel to trail after the pivot and thus a caster wheel can be PULLED in any direction but cannot be PUSHED at all. Caster is applied to a bicycle or motorcycle in a similar manner as shown in Fig. 38-20

You are familiar with the fact that a bicycle can be ridden and steered without holding the handlebars. As a single front wheel cannot have camber or sidewise king pin inclination the king pin or bicycle fork is inclined backward at the top to obtain caster and the desired stability or automatic steering effect.



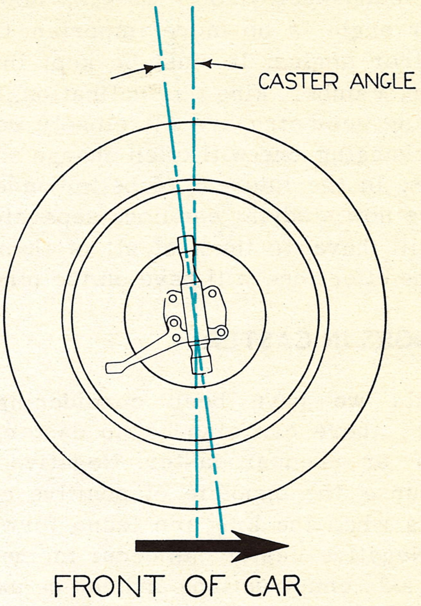
38-20. Here the center line of the king pin is not vertical but the lead is the same as in a furniture caster.

In order to better understand just how this works we will exaggerate the caster angle of the front fork of a bicycle as in Fig. 38-21. It will be obvious from this illustration that turning the wheel to right or left will lift the weight of the bicycle. Caster is applied to an automobile wheel in the same manner as shown in Fig. 38-22 and the results are identical.

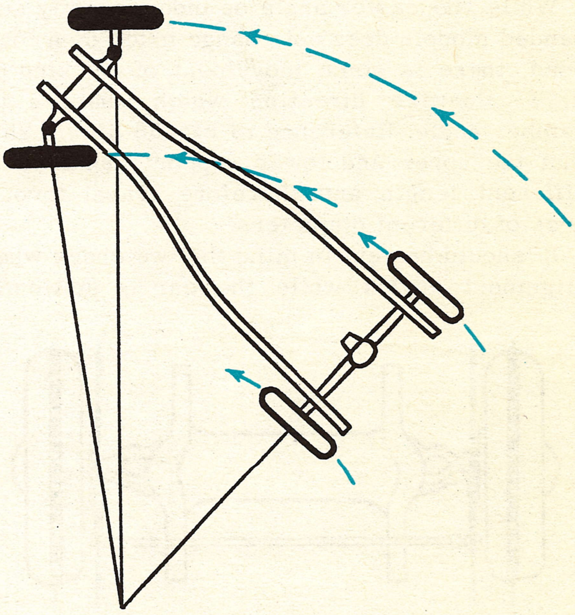


38-21. Exaggeration here shows that turning the fork will cause the bicycle frame to rise.

An automobile with excessive caster will be lifted each time the wheels are turned to right or left. The result is hard steering and violent straightening up after a turn.



38-22. Lead is obtained in automobiles by inclining the top of the king pin toward the rear of the car.



38-23. All four wheels travel in different size circles when the car is steered to right or left.

We have now considered two methods of obtaining an automatic steering effect:

1 - The combination of camber and king pin inclination which is used on practically all independently suspended models.

2 - The use of positive caster which was

used on practically all solid axle models.

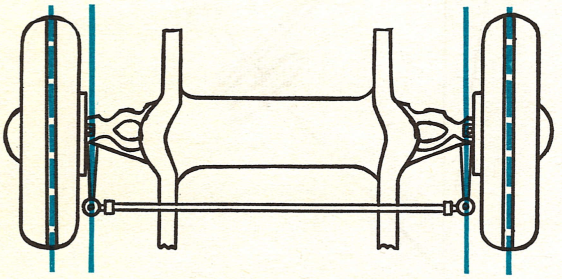
Before the general adoption of independently sprung front wheels the caster angle was perhaps the most important angle to check. On independently suspended front wheels, however, the caster angle is no more important than any of the other angles. It must be kept in mind that caster, camber, king pin inclination, toe-in and steering geometry are all closely related and that changing one will often change some of the others. In the interest of better understanding we are now studying each one separately. Later we will have to think of all of them together and the effect one will have on the other.

CHANGES IN CASTER

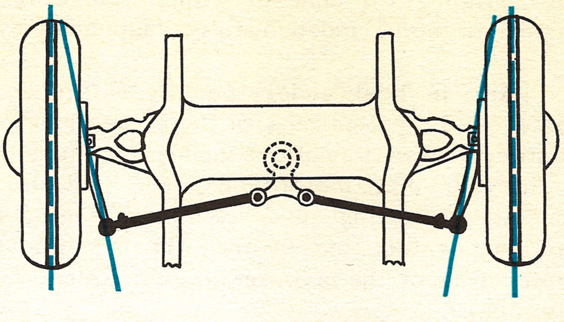
While we have been considering positive caster, there can also be no caster, negative caster or unequal caster. Negative caster is of course the opposite of positive caster and occurs when the king pin leans forward at the top. Negative caster can occur momentarily on solid axle constructions and can be exceedingly dangerous. It is less liable to occur on independently suspended wheels because of the difference in construction.

While the caster angle on independently suspended models does not change much on a rough road, there is some movement of the king pin in a sidewise direction which changes the camber angle. Reference to Fig. 38-13 will show that the upper and lower support arms are of different length and therefore travel through arcs of different diameters.

It should be kept in mind that we check wheel alignment angles while the car is stationary because we cannot check the car in rapid motion. Our objective however is to obtain correct steering when the car is being driven on the road. An empty car rolling slowly over an alignment instrument may check correctly and then handle unsatisfactorily on the road. The loaded car may be covering 90 feet of rough road every second and the area of tire contact with the road is constantly changing.



38-24. If the steering arms were parallel with the wheels, the wheels could not toe-out, or travel in circles of different diameters when the car turns and therefore one wheel would be forced to slide sidewise.



38-25. The steering arm angles, if extended, would intersect somewhere near the center of the rear axle.

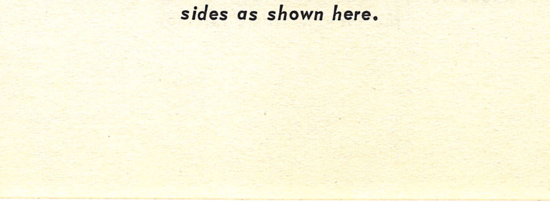
Furthermore the deflection of the car springs constantly changes the steering system angles and the effects of momentum and inertia on both car and load must be considered. That is why any wear in the parts of the steering system, weak springs, defective shock absorbers, unbalance, etc., must be corrected before any attempt is made to obtain correct wheel alignment angles.

STEERING GEOMETRY

In addition to the angles of caster, camber and king pin inclination---all measured with the wheels in the straight-ahead position---we must give consideration to the angularity of each front wheel when the car is turning. Because the wheels are in the straight-ahead position only about half the time the car is in operation, any untrue rolling action will destroy the tire tread very rapidly.

The front wheels must be parallel if true rolling contact is to be obtained when the car is going straight ahead, but if the wheels are parallel while turning, one wheel will be forced to slip sidewise. This is because the wheels are rolling on circles of different size. This is shown in Fig. 38-23.

Such being the case, it will be necessary for



38-26. With the steering arms at an angle with the wheels, there is a change in the rate of movement between the right and left sides as shown here.

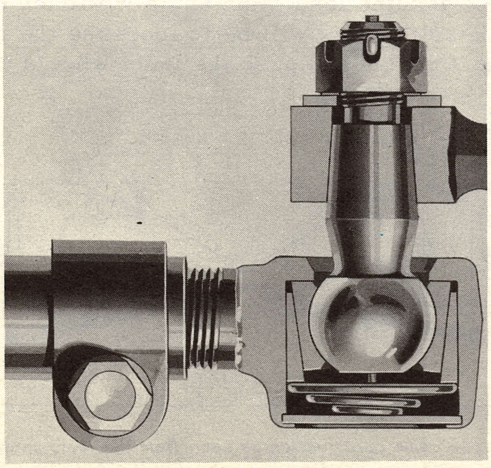
the wheels to set at a different angle with the chassis when turning the car. The proper angles result in the wheels being toed-out, or farther apart in front than behind. However, we want them parallel as soon as we straighten out again. Both objectives can be obtained by setting the steering arms at an angle with the wheels as shown in Fig. 38-24 and 38-25.

The theory of this design is that when the car is being turned the steering arm on the inside of the turn moves toward the center line of the wheel spindle and speeds up. The other steering arm is moving away from the center line of the spindle and slows down. This is illustrated in Fig. 38-26. Therefore the outer wheel does not turn as far as the inner wheel. A typical layout calls for 23 degrees angularity on the inner wheel while the outer is turning 20 degrees. The amount of difference varies with the car design and is specified by the car manufacturer.

Special gauges are available for measuring these angles and each wheel must be measured because the error, if any, could be in either or both steering arms. If the arms are bent, it is desirable to replace them rather than try to correct them by bending. This is true of steering spindles also when they are bent.

The reason for installation of new parts is safety. If these items are straightened cold, strains are set up within the metal that may result in eventual breakage. If they are heated to straighten them, there is a possibility of destroying the heat treatment process of manufacture which may weaken the parts. Either condition is dangerous.

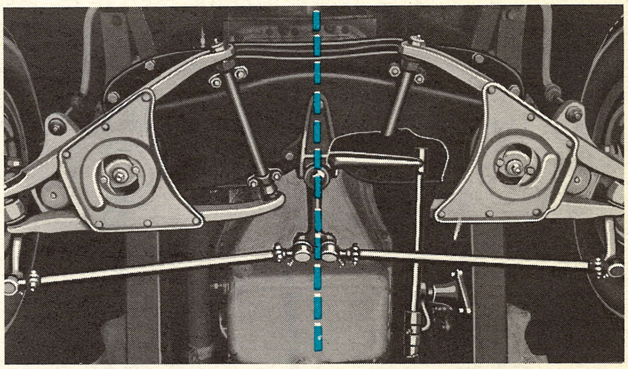
Of course the improper alignment of the front wheels when turning may be due to incorrect adjustment of the tie rod or rods. The tie rods can be adjusted in most cases. See Fig. 38-27. If they are not adjustable, (some of them are not) it will be necessary to replace them in order to obtain true and correct steering geometry.



38-27. Typical tie-rod end with threaded adjustment.

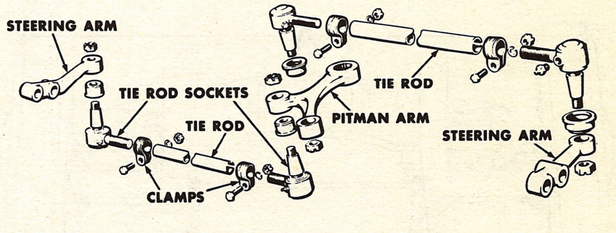
TOE-IN

Before attempting adjustment of the steering tie rods where two rods are used it is necessary to have the steering gear and the center steering arm in the midway position. This is accomplished by disconnecting both tie rods and setting the steering gear on the "high spot." This can be done by turning the steering wheel from extreme left to extreme right and counting the turns of the wheel required. The wheel is then turned half way between the two extremes which should be the straight-ahead position.



38-28. The intermediate steering arm—if used—should be centrally positioned with the wheels in the straight-ahead position.

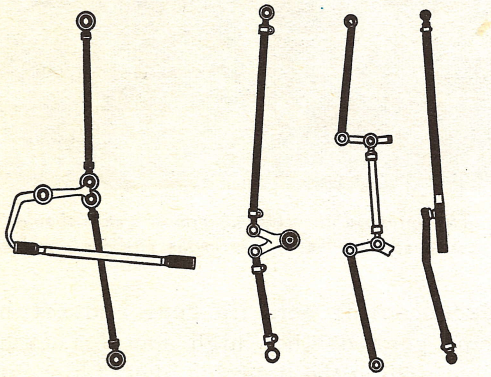
With the steering gear in the exact middle, the next point is the center steering arm (if used). This center steering arm should be in the middle as shown in Fig. 38-28. The wheels should now be lined up in the straight-ahead position. This can be done by drawing a chalk line or similar string along the wheels from front to rear. If the tread is wider in the rear than in front, it will be necessary to place blocks or spacers of the proper thickness on the outside of the front tires.



38-29. Exploded view of tie-rod assembly shows various points at which adjustment may be made.

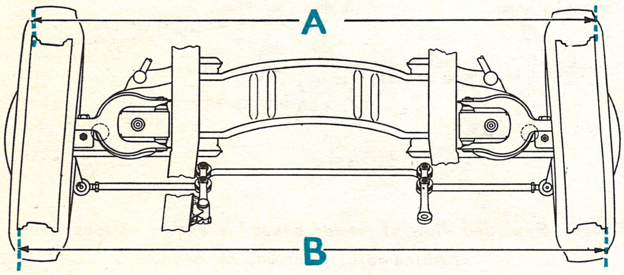
Now with the steering wheel, the intermediate steering arm and the front wheels all placed thus carefully in the straight-ahead position the tie rods are adjusted---one at a time---to the proper length. During this adjustment procedure the steering wheel, steering arms and wheels must not be moved. If the range of adjustment is insufficient it usually indicates a bent steering arm on one or both sides.

At the time of the foregoing adjustment the proper amount of toe-in as specified by the manufacturer is provided. Proper adjustment of the tie rods is not a simple matter of unscrewing on one end of one tie rod to get the wheels to toe-in to the dimension specified by the car manufacturer. Typical tie rod arrangements are shown in Figs. 38-29 and 38-30. If these adjustments are properly made the steering geometry as checked on the alignment gauges should be correct as specified by the car manufacturer. If not, one or both of the steering arms are probably bent.

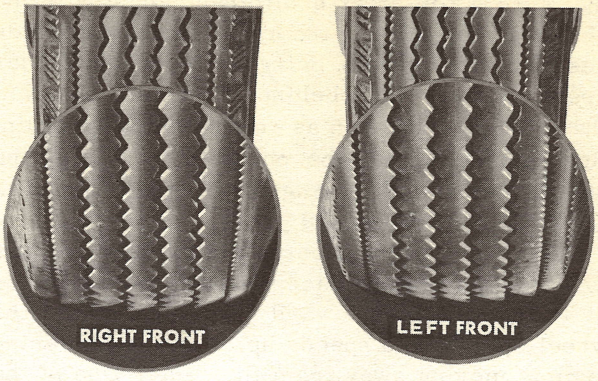


38-30. *Various arrangements of tie-rod connections.*

The amount of toe-in, see Fig. 38-31, (sometimes toe-out) specified by the car manufacturer is intended to compensate for the forces which cause the wheels to spread in front when the car is in motion. The tire flattens on the tread and spreads out on the road to cover enough area to cause serious wear, see Fig. 38-32, if the wheels do not run parallel. The tie rods are supposed to hold the wheels parallel, but such is not always the case when the car is in motion.



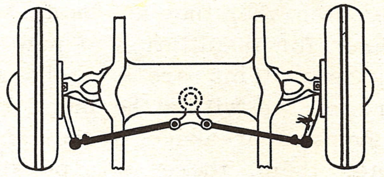
38-31. *The difference in measurement between A and B is the amount of toe-in (or toe-out).*



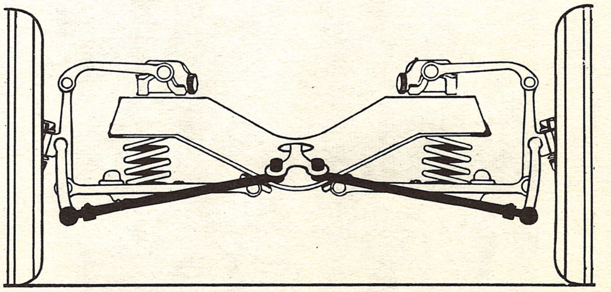
38-32. *Condition of tread wear due to improper adjustment of toe-in which causes tires to drag sidewise.*

CHANGES IN TOE-IN

For example, observe the typical construction shown in Fig. 38-33. Seen from above the tie rod appears rigid. Seen from the rear as shown in Fig. 38-34 the same construction shows that the inner ends of both rods are higher than the outer ends. Obviously therefore if the frame---to which the inner ends are attached---is lowered, as by a load placed on it, the two tie rods will tend to assume less of an angle with each other. The result of this will be to increase the length of the tie rod and push the front wheels closer



38-33. *Seen from above, these tie rods would appear to hold the wheels parallel.*



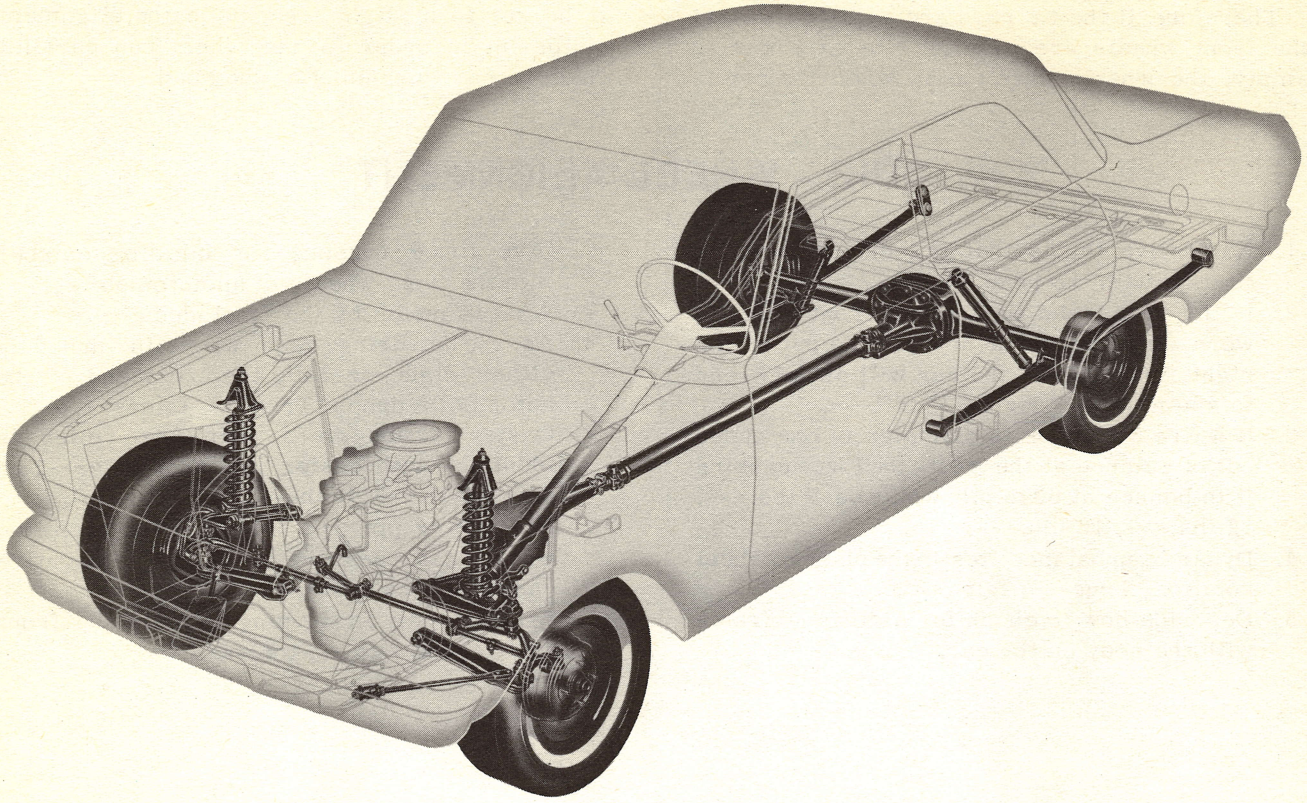
38-34. *The same construction as seen from the rear, shows that weight on the frame will change the length of the tie rod and therefore the amount of toe-in of the wheels.*

together in front which would increase toe-in.

Therefore if the tie rods are adjusted so that the front wheels are parallel when the car is empty, the wheels may toe-in when the car is loaded. For this reason the wheels might have to be set to a slight toe-out on the alignment equipment in order to have them run parallel when the car is running on the road.

QUIZ - WHEEL ALIGNMENT

1. Name five things that influence tire tread contact with the road surface.
2. If the tire tread on the left front wheel is worn smooth, and a new tire is put on the right front wheel, the car will usually tend to steer to the: right---, left---.
3. If a tire 30 inches in diameter is one ounce out of balance at the tread, the force causing it to bounce at 60 m.p.h. would be: 9 lbs.---, 12 lbs.---, 16 lbs.---.
4. Dynamic unbalance lies in the plane of wheel rotation. True---, false---.
5. Describe how to check for a diagonal frame with the body on the car.
6. Give three reasons for building camber into the front wheels of an automobile.
7. What is meant by the "included angle?"
8. As the steering gear wheel is turned to either right or left, the front end of the automobile drops. True---, false---.
9. Caster action in a furniture roller is identical with caster in: a bicycle---, an automobile---, both---.
10. If the king pin tips forward at the top, the wheel has: positive caster---, negative caster---, no caster---.
11. When a car is turning, should the front wheels: toe-out---, toe-in---?



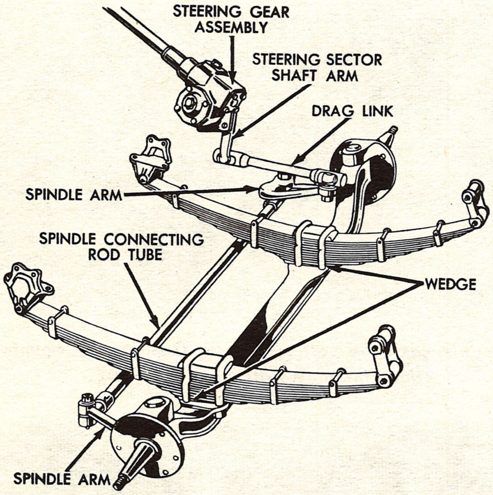
Phantom view, front and rear suspension, Chevy II.

SPRING SUSPENSION

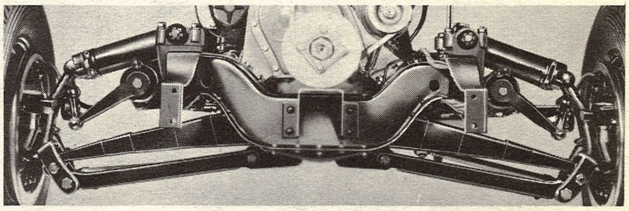
LEAF SPRINGS

Automobile springs are used in a wide variety of types and mountings. Leaf or plate springs are ordinarily used with solid axles. See Fig. 39-1. Leaf springs have also been used for independent suspension of the wheels by placing them crosswise of the frame. See Figs. 39-2 and 39-3. In many cases leaf springs are used on the rear axle in combination with some other type of spring on the front suspension. See Fig. 39-4.

When used on the rear of the vehicle, leaf springs are usually placed parallel with the frame. When so used on the rear, leaf springs absorb the torque of the driving wheels as they are attached to the frame and also rigidly attached to the rear axle. The front half of the leaf springs also act as radius rods to convey the driving force from the wheels to the frame. As the springs do not bend sidewise to any extent and are shackled to the frame, they serve as stabilizers to control side sway of the chassis.



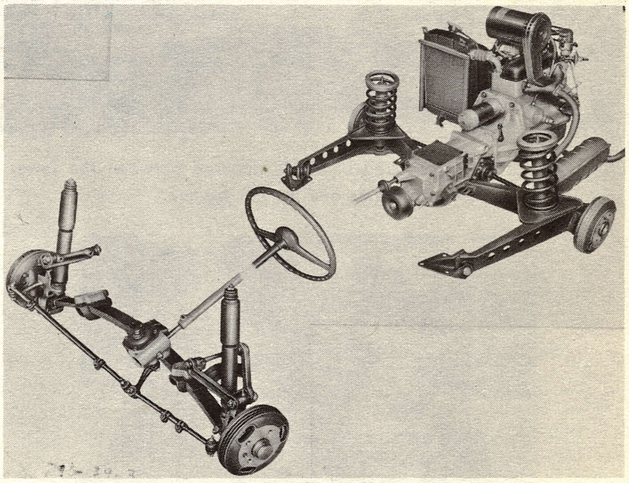
39-1. Typical leaf spring suspension arrangement as used with a solid front axle. The wedges shown are to regulate axle caster.



39-2. Leaf spring equipped with metal covers and mounted crosswise for use with independently suspended front wheels.

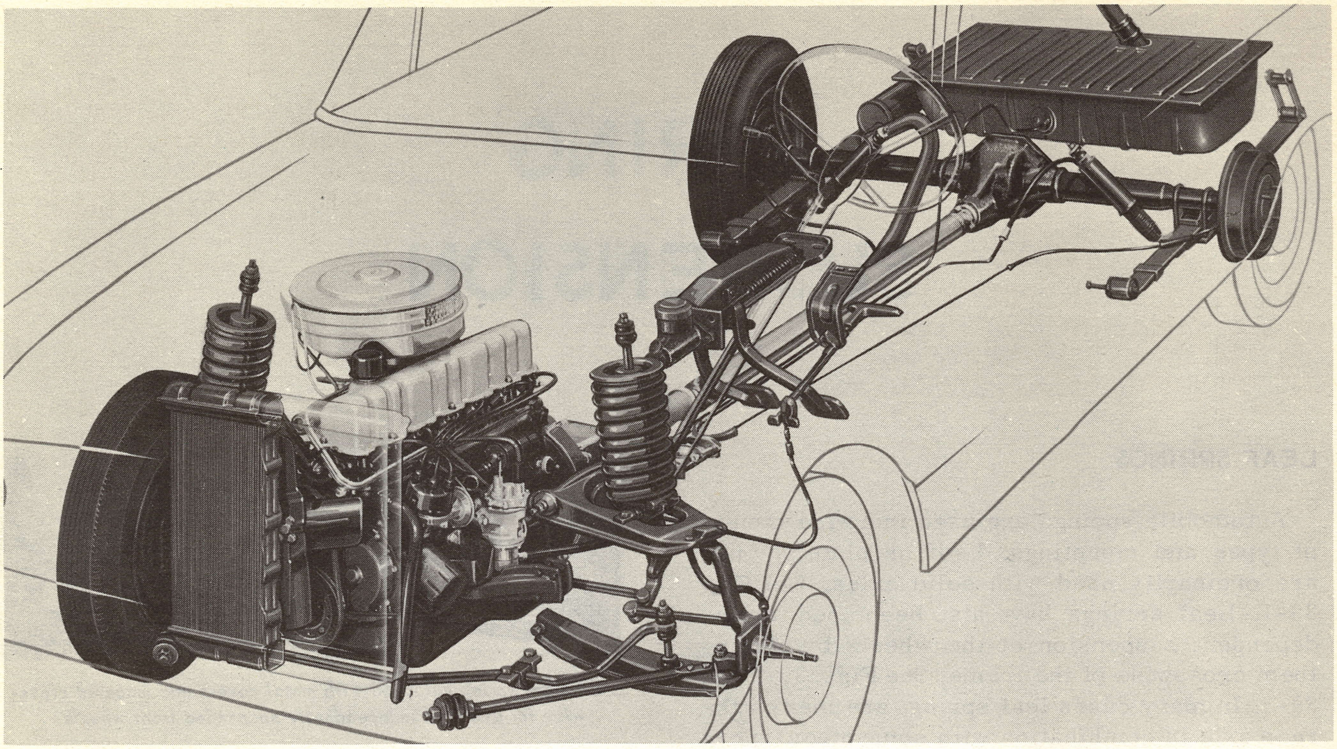
COIL SPRINGS

Coil springs used on automobile suspension systems are usually of the compression type as used either front or rear. The springs are often mounted between the upper and lower control arms of the front suspension system as shown in Fig. 39-5. They may also be mounted between the upper control arm and the body as shown in Fig. 39-6.

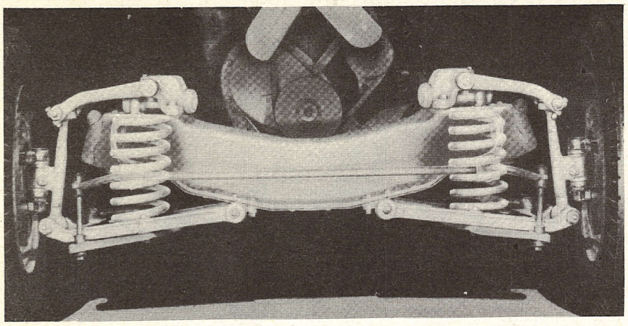


39-3. Independent front suspension by means of a transverse single spring on the Italian Fiat. Rear coil springs are mounted on radius arms.

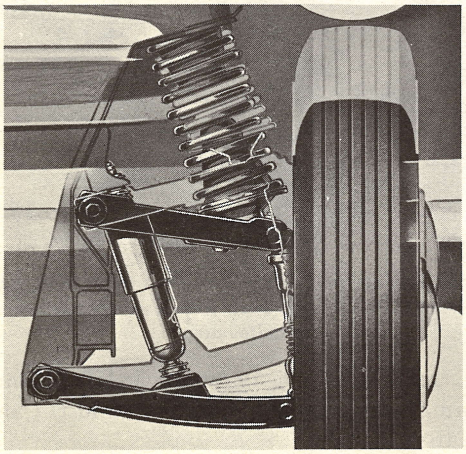
When used on both front and rear as shown in Fig. 39-7, it is customary to use radius rods



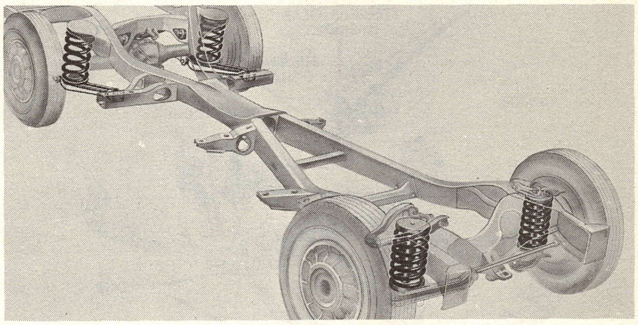
39-4. *Leaf springs in the rear, combined with coil springs in front. In this case, the upper end of the coil springs is attached to the body structure.*



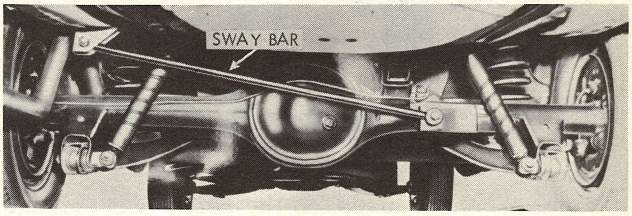
39-5. *Coil springs as used in front, mounted between the lower control arms and the car frame.*



39-6. *One method of placing coil spring between upper control arm and body structure.*

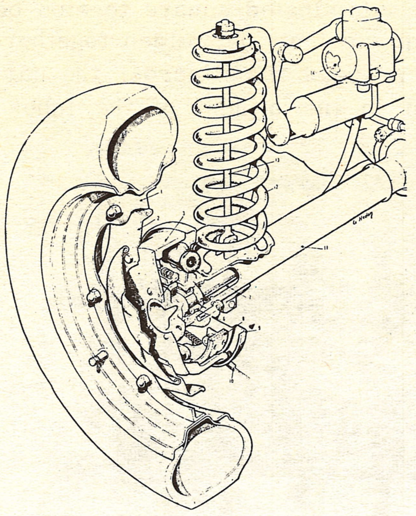


39-7. *In this case the coil springs at the rear are mounted between the radius arms and the frame.*



39-8. *Method of attaching sway bar to rear axle and frame of Chevrolet. Attaching bolts are rubber insulated.*

between the rear axle and frame. Also a sway bar is usually attached to prevent side sway of the body. See Fig. 39-8. This is not always done however, as rear coil springs can be mounted between the frame and a swinging half axle as shown in Fig. 39-9. In this case the



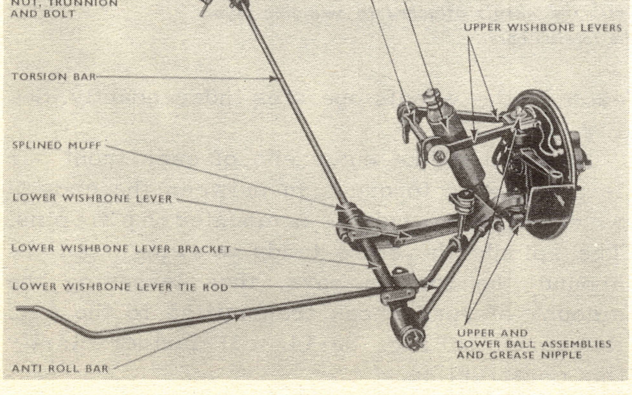
39-9. Swing axle mounting of coil springs at rear of Renault.

independently suspended rear wheels have a sturdy axle housing attached to the differential which is bolted to the frame.

TORSION BARS

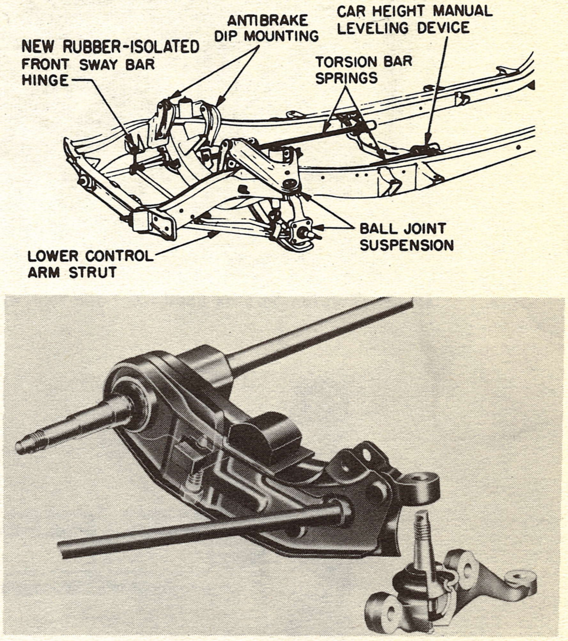
Although various types of torsion bar suspension systems have been used on passenger cars in Europe for many years, they did not receive much attention here until recently. They have been used here on buses, trailers, race cars and army tanks for several years.

In the simplest terms, torsion bar suspension is a method of using the flexibility of a steel bar or tube twisting lengthwise, instead of a leaf or coil spring between the frame and axles. In the case of an independently suspended front system using lengthwise bars, one end of the bar would be attached to the control arm. The other end is anchored to the car frame in such manner that as the wheel rises and falls, the bar twists all along its length. See Figs. 39-10 and 39-11.



REACTION LEVER AND CLAMP BOLT
ADJUSTMENT BARREL NUT, TRUNNION AND BOLT
TORSION BAR
SPLINED MUFF
LOWER WISHBONE LEVER
LOWER WISHBONE LEVER BRACKET
LOWER WISHBONE LEVER TIE ROD
ANTI ROLL BAR
UPPER WISHBONE LEVER BRACKET
SHOCK ABSORBER
UPPER WISHBONE LEVERS
UPPER AND LOWER BALL ASSEMBLIES AND GREASE NIPPLE

39-10. An early user of torsion bars was the Jaguar with the construction shown here.



NEW RUBBER-ISOLATED FRONT SWAY BAR HINGE
ANTIBRAKE DIP MOUNTING
CAR HEIGHT MANUAL LEVELING DEVICE
TORSION BAR SPRINGS
BALL JOINT SUSPENSION
LOWER CONTROL ARM STRUT

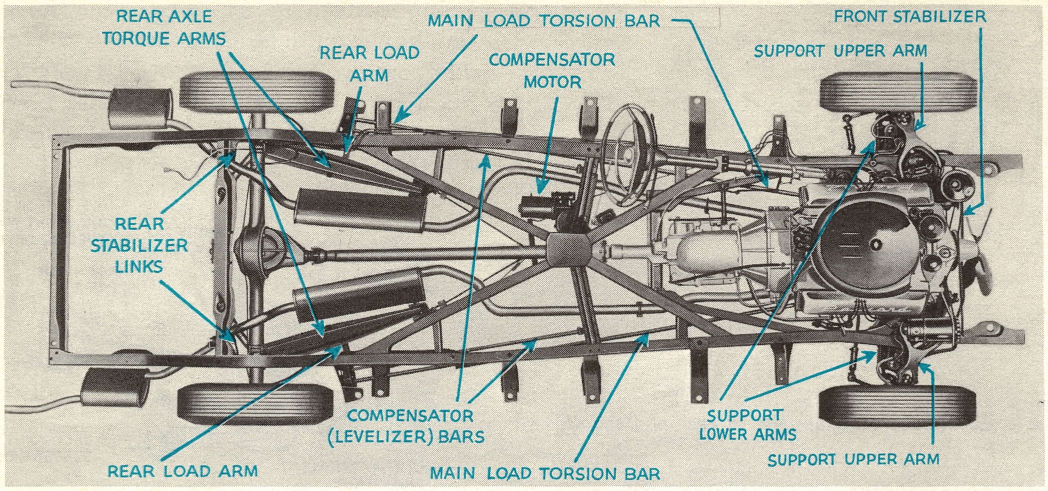
39-11. Torsion bars are mounted in this manner for use on the front suspension of Chrysler built cars.

Torsion bars are used for rear wheel suspension as well as front wheel springing. Examples of torsion bars front and rear are supplied by Packard and Volkswagen. See Figs. 39-12 and 39-13, 39-14 and 39-15.

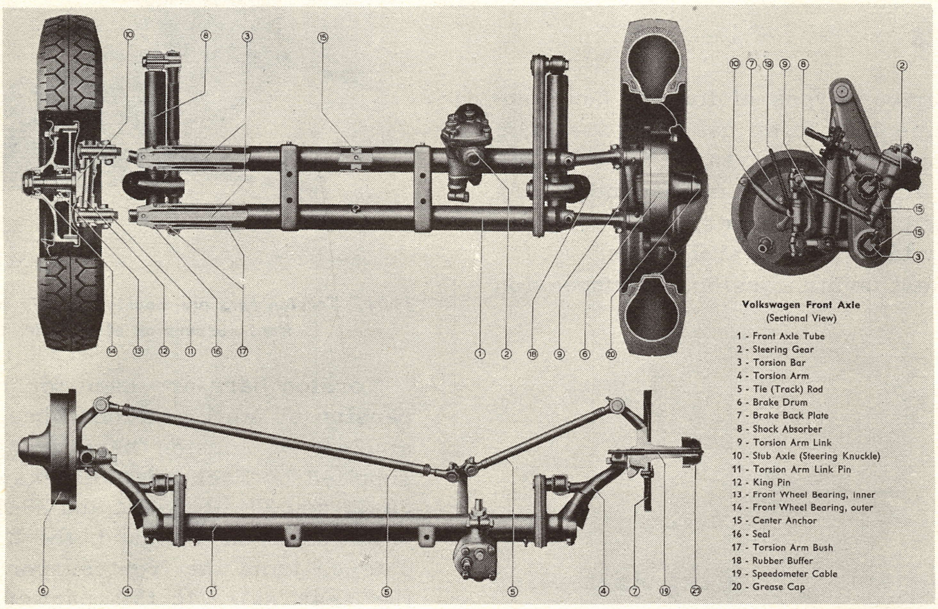
As used on Packard, the bar on each side extends from the front support arm almost to the rear axle. In this particular installation, the main load torsion bar should not be confused with the shorter compensator bar. This compensator bar is connected with the torsion bar as a part of a car leveling device.

This levelizer is added to the torsion bar system to regulate the height of the car and keep it level regardless of load. It is electrically controlled, automatic in action and serves to increase or decrease the tension or "twist" of the main load torsion bars.

In operation, when the loading at either end of the car is increased or decreased, the center section of the main torsion bar will twist or rotate causing the control switch to operate the electric motor in one direction or the other. This causes the connecting links to move inward or outward to rotate the shorter compensator bars. These bars, in turn, cause the rear load arms to pivot and either raise or lower the rear end of the car to make it level with the front end. The compensator does not function to compensate for road irregularities---it functions only when the car load is changed.


REAR AXLE TORQUE ARMS
REAR LOAD ARM
MAIN LOAD TORSION BAR
COMPENSATOR MOTOR
FRONT STABILIZER
SUPPORT UPPER ARM
REAR STABILIZER LINKS
COMPENSATOR (LEVELIZER) BARS
REAR LOAD ARM
MAIN LOAD TORSION BAR
SUPPORT LOWER ARMS
SUPPORT UPPER ARM

39-12. Torsion bars as used front and rear with solid rear axle and independently suspended front wheels.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3
Volkswagen Front Axle
(Sectional View)
1 - Front Axle Tube
2 - Steering Gear
3 - Torsion Bar
4 - Torsion Arm
5 - Tie (Track) Rod
6 - Brake Drum
7 - Brake Back Plate
8 - Shock Absorber
9 - Torsion Arm Link
10 - Stub Axle (Steering Knuckle)
11 - Torsion Arm Link Pin
12 - King Pin
13 - Front Wheel Bearing, inner
14 - Front Wheel Bearing, outer
15 - Center Anchor
16 - Seal
17 - Torsion Arm Bush
18 - Rubber Buffer
19 - Speedometer Cable
20 - Grease Cap
6
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7
19
20

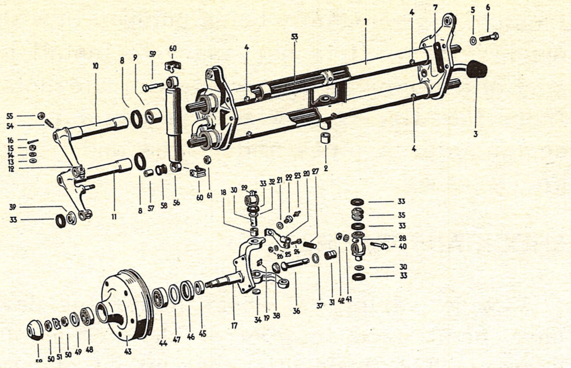
39-13. Volkswagen uses dual torsion bars in front with the wheels attached to swinging lever arms that trail behind the torsion bars.

Volkswagen uses a construction that is unique in several ways. All four wheels are independently suspended but two different types of torsion bars are used. These are so mounted that each of the wheel spindles trail behind the transverse torsion bars on a lever arrangement.

The front axle consists of two rigidly joined tubes bolted to the frame. Within each of these tubes is a laminated square torsion bar made up of flat steel strips welded together at each end. These bars reach across the car but are anchored in the middle of the tubes so that each of the wheels operates independently. See Fig. 39-13.

Attached to the outer end of each front bar is a lever or torque arm between the ends of which the wheel spindle is mounted on pivot pins. The spindle therefore tends to swing in an arc around the torsion bars, thus lessening the amount of road shock transmitted to the car. Reference to Fig. 39-14 will further clarify this construction.

The rear suspension employs one round torsion bar on each side instead of the long bars



39-14. Volkswagen front suspension. 10-suspension arm, upper, 11-suspension arm, lower, 53-laminated square torsion bar, upper.

used in the front. These bars are splined on each end as shown in Fig. 39-15. Here also the wheels trail behind the torsion bars on the end of a lever arm.

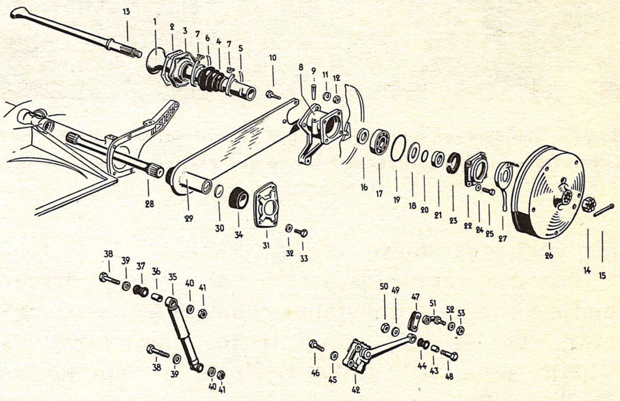
AIR SUSPENSION

Recently used on passenger cars, air suspension is not new as it has been used on buses and trucks for some time. As shown in Fig. 39-16, a complete installation involves an air compressor, supply tank and the necessary valves, piping and controls.

Air suspension systems do much more than merely cushion the ride. They keep the car level fore and aft regardless of uneven loading, they prevent sidewise tipping and can also hold the body at constant height regardless of load. See Fig. 39-17.

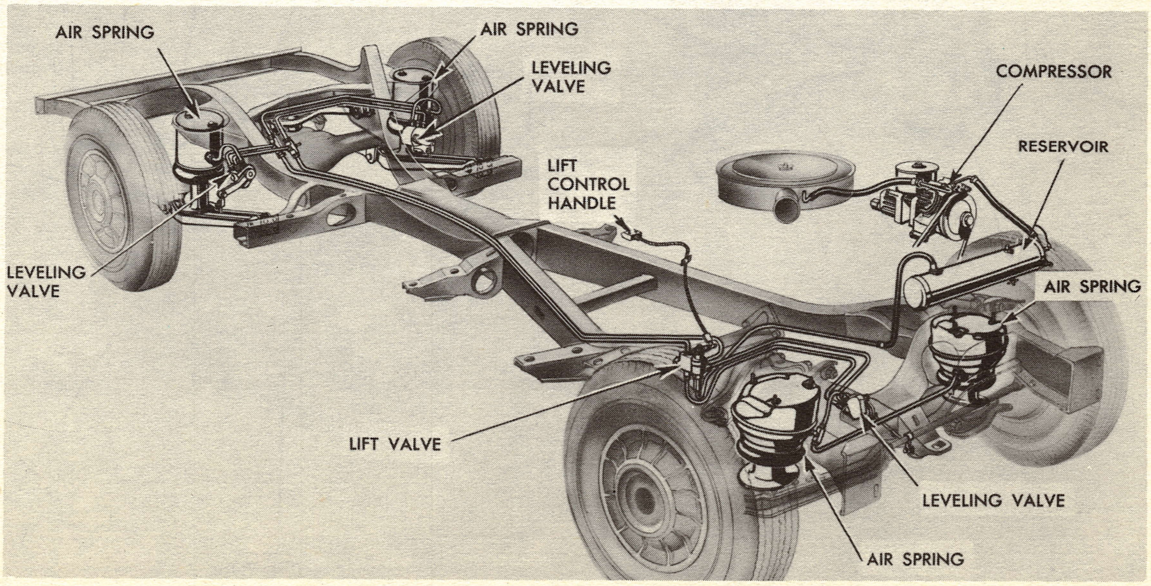
By means of automatically operated control valves the pressure is increased on either side or at front or rear as required to keep the car level. Other automatic controls can be adjusted to increase or decrease the pressure in all springs to hold the body at any desired height from the road. These various units are identified in Fig. 39-18.

Air units are also used in combination with metal springs to compensate automatically for overload conditions. Thus the air spring acts as a "booster" or overload spring. See Fig. 39-19.

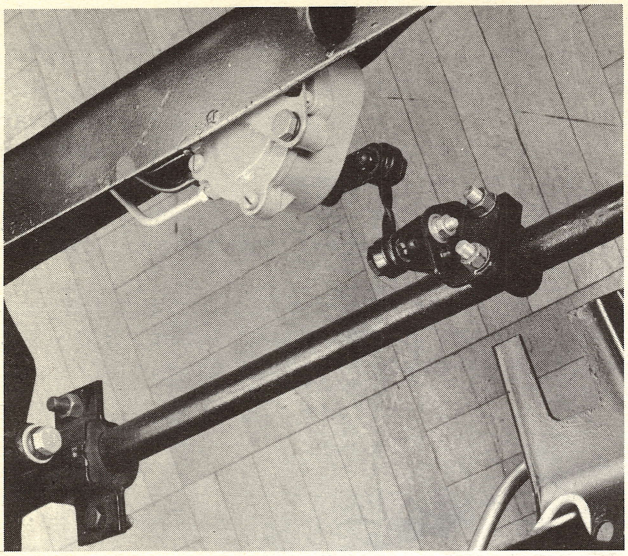


39-15. Volkswagen rear suspension. 1-rear axle tube, 8-rear axle shaft bearing housing, 28-torsion bar, 29-spring plate.

The air chambers or air springs at each wheel are made in a wide variety of shapes and sizes as indicated in Fig. 39-20. A typical



39-16. Typical air suspension system as used by Cadillac.



39-17. *One type of automatic height control valve, mounted between frame and stabilizer bar where any change in load causes it to function.*

air spring is shown in Fig. 39-21.

The air compressor is usually engine driven and maintains a constant pressure in the reservoir. The air is piped to the control valves which send it to the bellows or spring as needed. When air pressure is reduced in any spring, the air is exhausted directly in an open system or to a low pressure tank in a closed system.

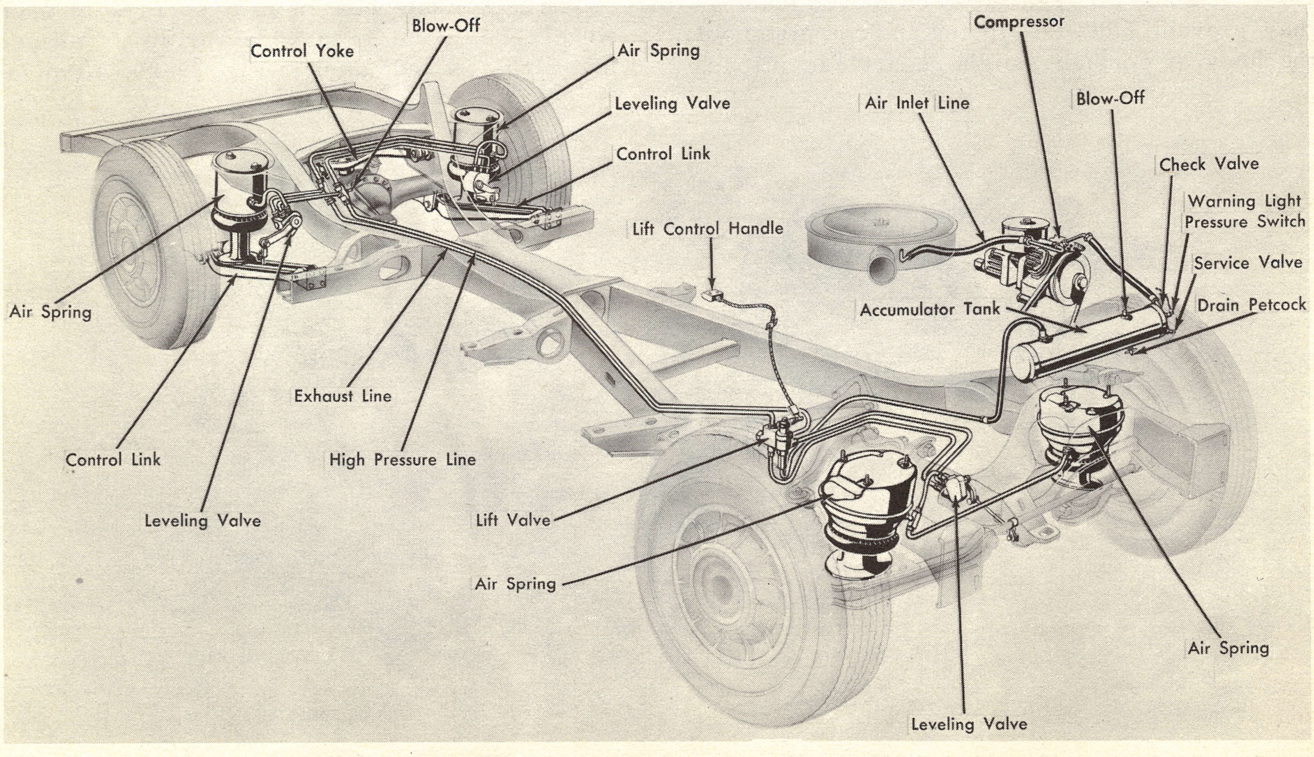
In either case, whether the air is pumped from the low pressure reservoir into the high pressure reservoir in the closed system, or where fresh air is constantly being pumped in with the open system, it is necessary to install some sort of filter or condenser to eliminate moisture from the air. Otherwise this moisture would accumulate in pipes and valves and freeze in cold weather.

SHOCK ABSORBERS

A wide variety of shock absorbing devices have been used to control the action of car springs. The hydraulic instrument eventually established dominance over other devices and the "direct action" or "telescoping" two-way type of hydraulic unit is now almost universally used. See Fig. 39-22. One end of this unit is attached to the axle and the other end fastened to the frame. Quite often the rear units are mounted at an angle to assist in restricting sidewise movement as well as vertical movement. See Fig. 39-23.

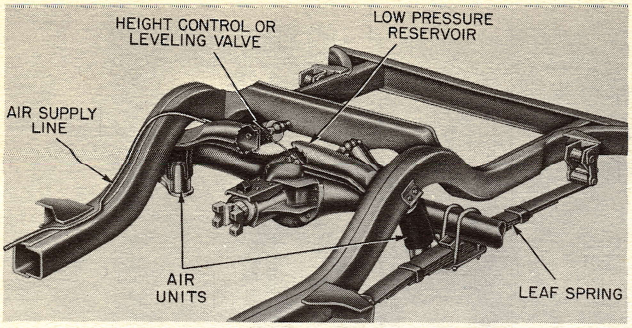
The operating principle is the same in all of them and consists of forcing a fluid through restrictions to slow down and control the rapid movement of the car springs. By means of spring loaded valves the flow of fluid through the piston is controlled and thus the sometimes violent action of the springs is regulated. See Fig. 39-24.

It may be seen that if the axle moves slowly,

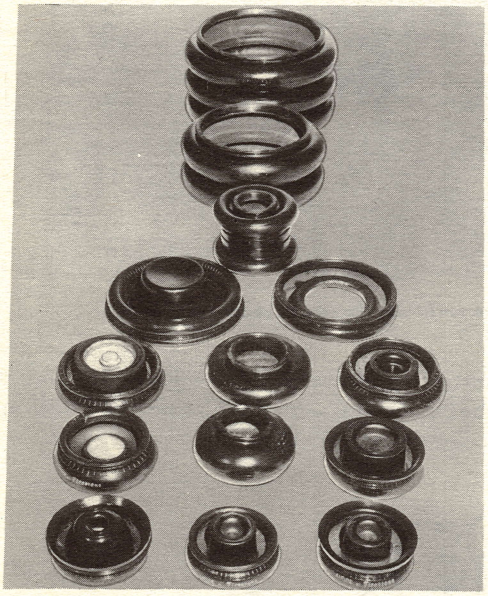


Blow-Off
Control Yoke
Air Spring
Leveling Valve
Control Link
Compressor
Air Inlet Line
Blow-Off
Check Valve
Warning Light Pressure Switch
Service Valve
Drain Petcock
Lift Control Handle
Accumulator Tank
Air Spring
Exhaust Line
Control Link
High Pressure Line
Leveling Valve
Lift Valve
Air Spring
Air Spring
Leveling Valve

39-18. *Identification of various units and controls in Cadillac system.*

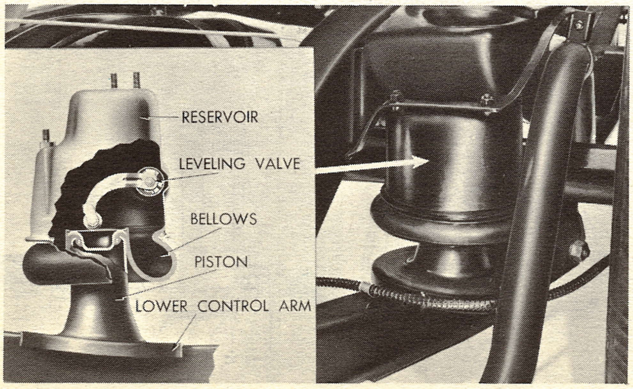

HEIGHT CONTROL OR LEVELING VALVE
LOW PRESSURE RESERVOIR
AIR SUPPLY LINE
AIR UNITS
LEAF SPRING

39-19. *Chrysler method of using air units in combination with leaf springs for overload conditions.*

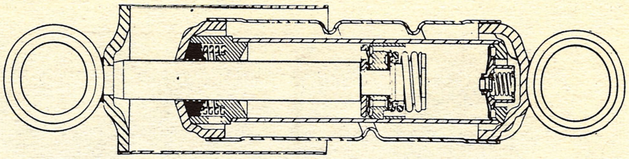


39-20. *Variety of air springs for 14 makes as made by Firestone.*

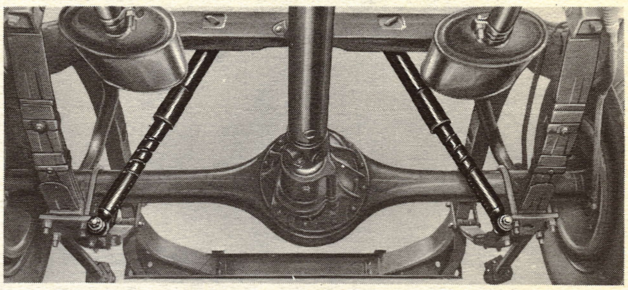
the resistance encountered by the piston in forcing the fluid through the valve will be light. However, if the axle movement is rapid or of considerable magnitude, the resistance will be much stronger because more time is required to force the fluid through the opening.


RESERVOIR
LEVELING VALVE
BELLOWS
PISTON
LOWER CONTROL ARM

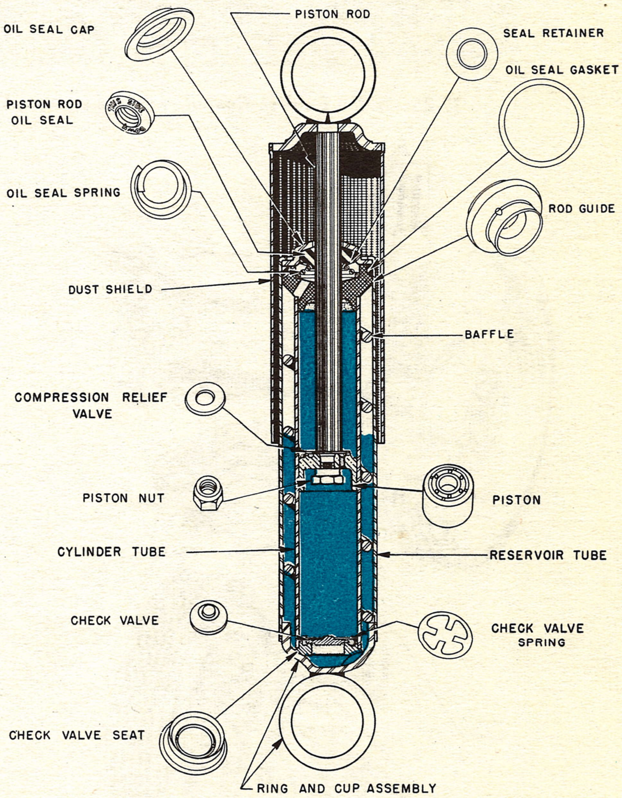
39-21. *Air spring unit as used by Chevrolet at rear axle.*



39-22. *Internal construction of typical two-way telescoping hydraulic shock absorber.*

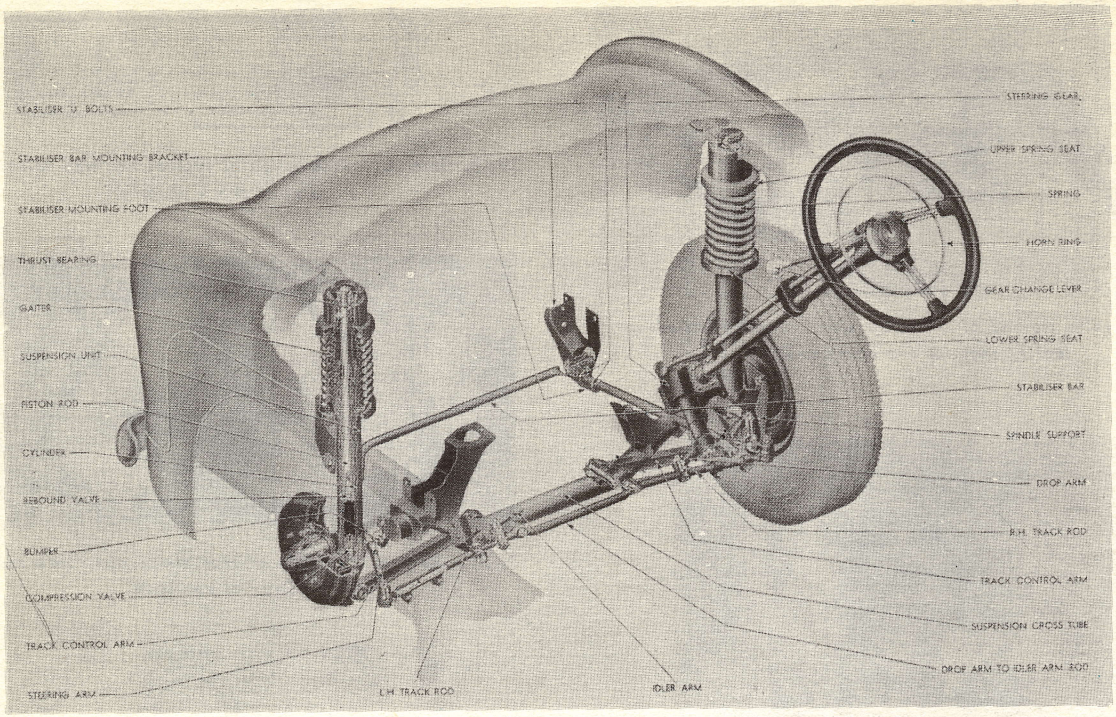


39-23. *Angular mounting of rear shock absorbers reduces side sway of car body.*

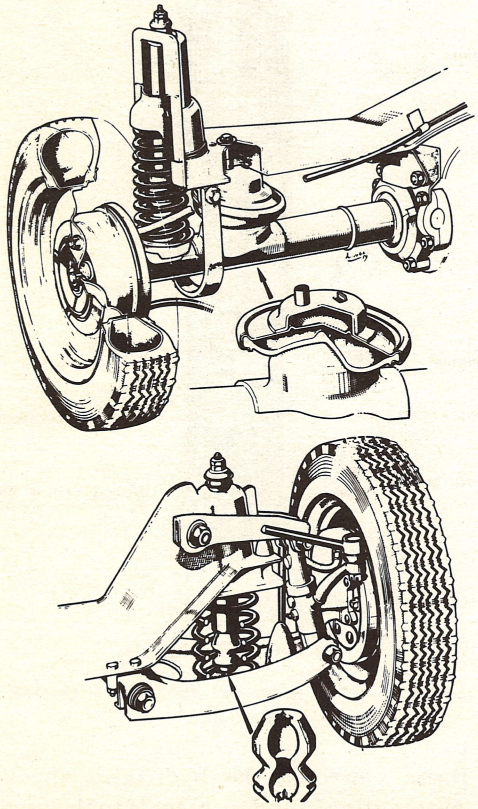

PISTON ROD
OIL SEAL CAP
SEAL RETAINER
OIL SEAL GASKET
PISTON ROD OIL SEAL
OIL SEAL SPRING
ROD GUIDE
DUST SHIELD
BAFFLE
COMPRESSION RELIEF VALVE
PISTON NUT
PISTON
CYLINDER TUBE
RESERVOIR TUBE
CHECK VALVE
CHECK VALVE SPRING
CHECK VALVE SEAT
RING AND CUP ASSEMBLY

39-24. *Location of valves to control fluid flow in Oriflow shock absorber.*

For these reasons, the hydraulic shock absorber automatically adapts itself to the severity of the shock. Thus a soft ride is obtained over small bumps and firm control is had over the spring action for large bumps. The instrument operates in both directions as spring rebound can be almost as violent as the original action.

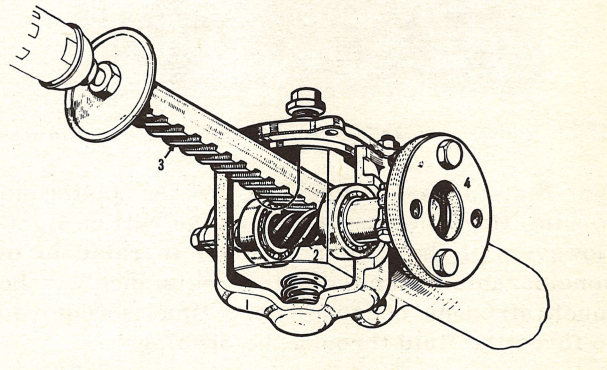

STABILISER 'U' BOLTS
STABILISER BAR MOUNTING BRACKET
STABILISER MOUNTING FOOT
THRUST BEARING
GAITER
SUSPENSION UNIT
PISTON ROD
CYLINDER
REBOUND VALVE
BUMPER
COMPRESSION VALVE
TRACK CONTROL ARM
STEERING ARM
L.H. TRACK ROD
IDLER ARM
STEERING GEAR
UPPER SPRING SEAT
SPRING
HORN RING
GEAR CHANGE LEVER
LOWER SPRING SEAT
STABILISER BAR
SPINDLE SUPPORT
DROP ARM
R.H. TRACK ROD
TRACK CONTROL ARM
SUSPENSION CROSS TUBE
DROP ARM TO IDLER ARM ROD

39-25. In the English Consul and Zephyr, the shock absorbers are built into the front suspension system.

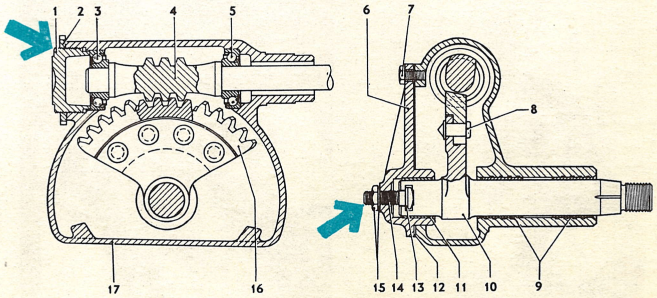


39-26. The French Renault construction includes pneumatic chambers with the coil springs both front and rear.

In some cases the front shock absorbers are built into, and are a part of the suspension system as shown in Fig. 39-25. In other cases pneumatic chambers are added to the shock absorbers as an additional control over spring action. See Fig. 39-26.



39-27. Rack and pinion type of steering gear as used on Renault.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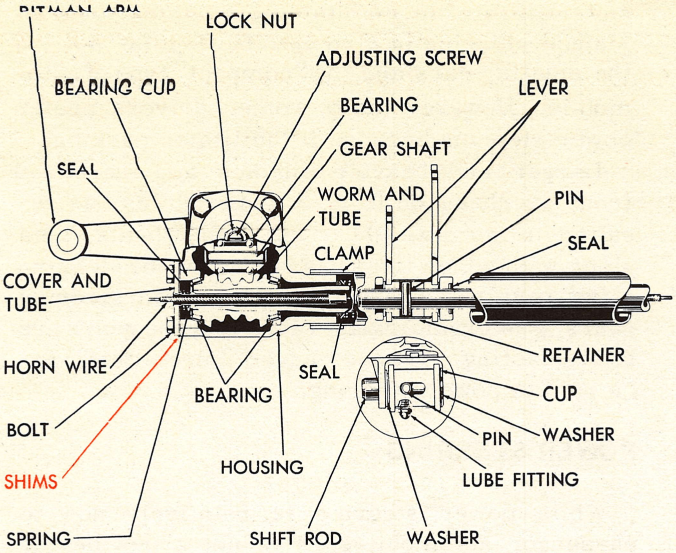
39-28. Worm and sector type of steering gear as used on English Bedford. 1-Worm bearings adjuster, 14-gear mesh adjuster screw.

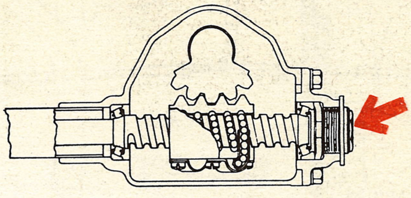

PITMAN ARM
LOCK NUT
ADJUSTING SCREW
BEARING CUP
BEARING
LEVER
GEAR SHAFT
SEAL
WORM AND
TUBE
PIN
CLAMP
SEAL
COVER AND
TUBE
RETAINER
HORN WIRE
SEAL
CUP
BEARING
BOLT
PIN
WASHER
SHIMS
HOUSING
LUBE FITTING
SPRING
SHIFT ROD
WASHER

39-29. *Adjustment of the worm gear shaft in this gear is by means of shims.*

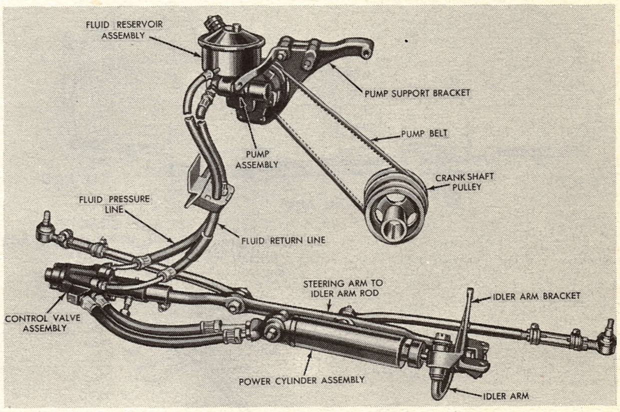
MANUAL STEERING GEARS

Several basic types of steering gears have been used. One is the rack and pinion type as shown in Fig. 39-27. Another is the worm and sector shown in Fig. 39-28. A different version of the worm and sector is shown in Fig. 39-29. The screw and nut type as shown in Fig. 39-30 is also popular.

As excessive looseness cannot be permitted in the steering gear unit, adjustment for wear is provided. Endwise control of the shafts is possibly the most important as wear between the gear surfaces is quite slow. Methods of adjustment are obvious from the illustrations.

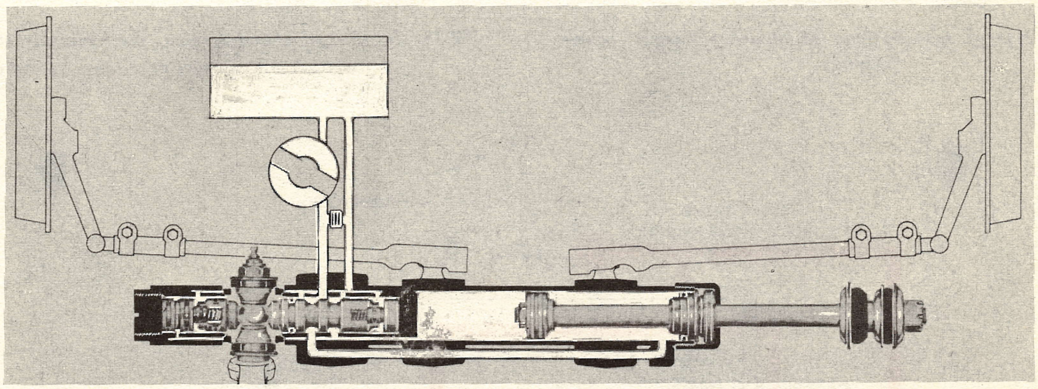


39-30. *In this steering gear, a threaded adjustment is provided at the lower end of the gear case.*

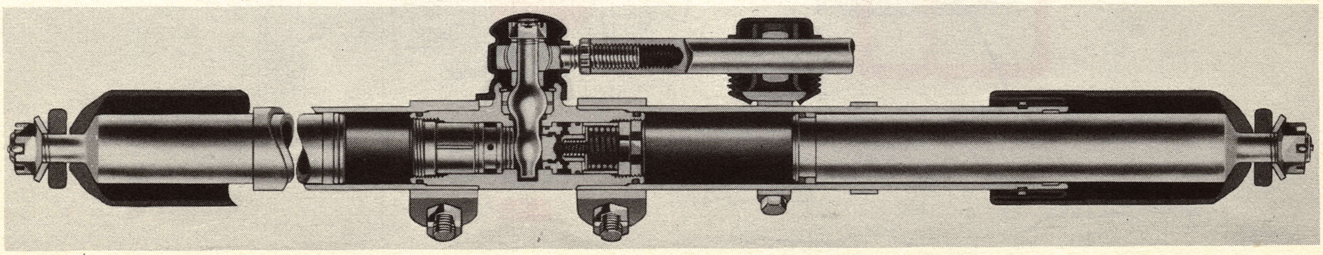

FLUID RESERVOIR ASSEMBLY
PUMP SUPPORT BRACKET
PUMP BELT
PUMP ASSEMBLY
CRANKSHAFT PULLEY
FLUID PRESSURE LINE
FLUID RETURN LINE
STEERING ARM TO IDLER ARM ROD
IDLER ARM BRACKET
CONTROL VALVE ASSEMBLY
POWER CYLINDER ASSEMBLY
IDLER ARM

39-31. *Linkage mounted Bendix system as used by Ford.*

Manual steering is entirely adequate for small cars with the engine in the rear. It is light, fast



39-32. *The control valve is integral with the power cylinder in this typical Monroe installation.*



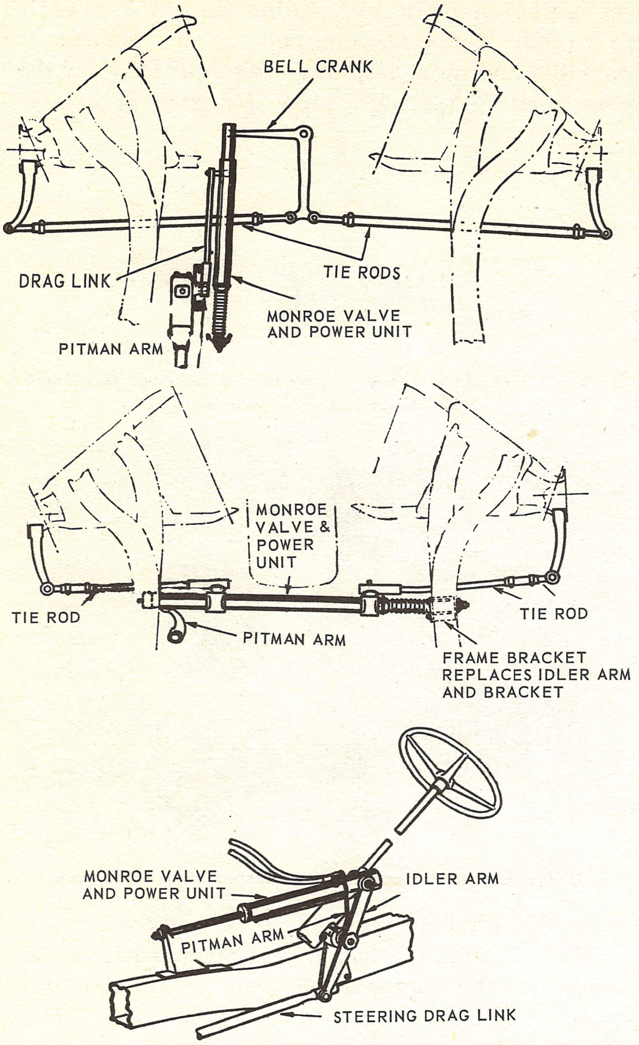
39-33. *In this Gemmer steering unit, the control valve is located between the power cylinders.*

and accurate in maintaining steering control. Manual steering is also satisfactory for most of the smaller cars and the "compact" type of automobile. However many women drivers prefer power steering because it facilitates parking.

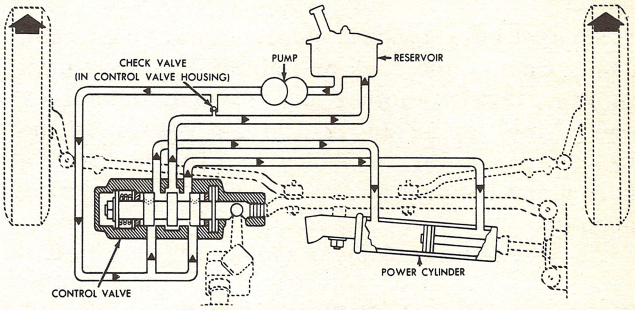
Larger and heavier engines and increased front overhang on U. S. A. automobiles has resulted in more weight on the front wheels. This along with wider tires has increased the steering effort required and therefore has meant steering gears with greater gear ratios. These gears are slower acting and have caused more attention to be paid to power steering.

POWER STEERING

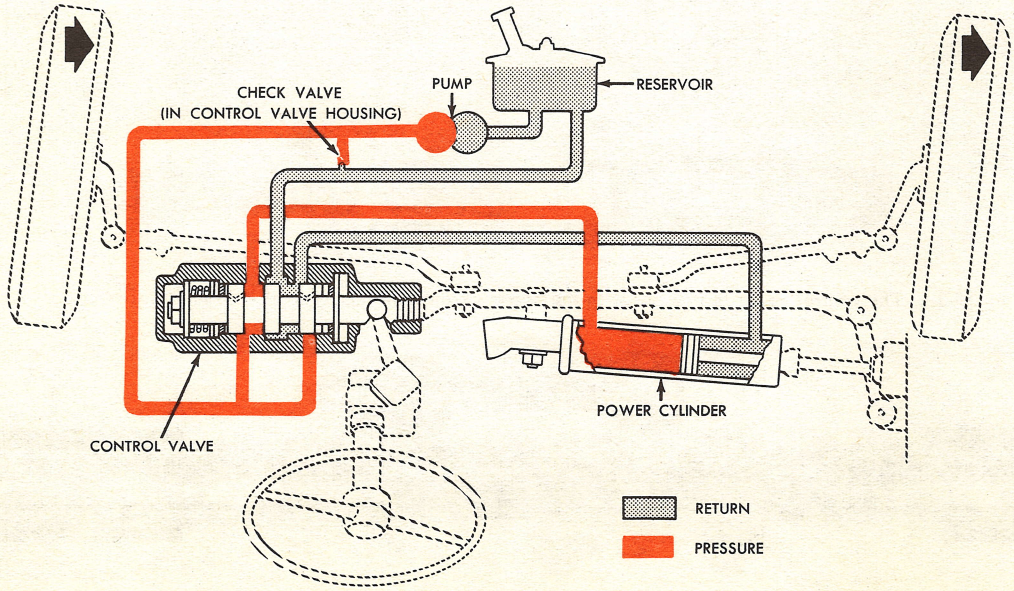
While power steering is relatively new to passenger automobiles, it is not a new device as it has been used on tractors and other off-the-road vehicles for many years. It has also been used on some trucks and buses. Several types are available: mechanical, hydraulic and pneumatic. We shall concern ourselves with the


BELL CRANK
DRAG LINK
TIE RODS
MONROE VALVE AND POWER UNIT
PITMAN ARM
MONROE VALVE & POWER UNIT
TIE ROD
PITMAN ARM
TIE ROD
FRAME BRACKET REPLACES IDLER ARM AND BRACKET
MONROE VALVE AND POWER UNIT
IDLER ARM
PITMAN ARM
STEERING DRAG LINK

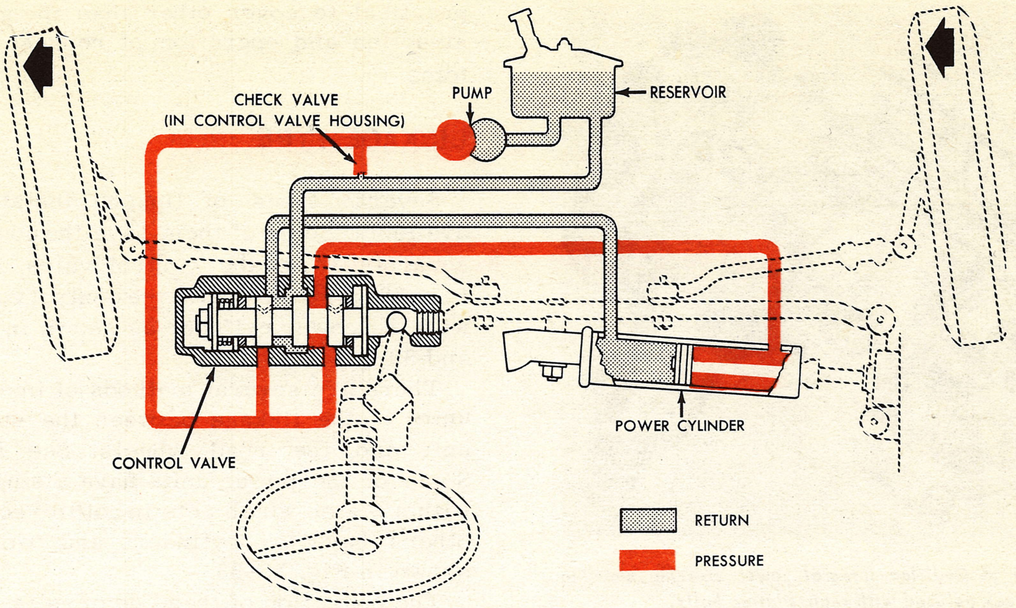
39-34. Three typical installations of steering linkage power boosters.


CHECK VALVE (IN CONTROL VALVE HOUSING)
PUMP
RESERVOIR
CONTROL VALVE
POWER CYLINDER

39-35. In straight ahead driving, the hydraulic fluid circulates throughout the system as shown by the arrows.


CHECK VALVE (IN CONTROL VALVE HOUSING)
PUMP
RESERVOIR
CONTROL VALVE
POWER CYLINDER
RETURN
PRESSURE

39-36. When a right turn is made, circulation is blocked and pressure builds up on one end of the piston.

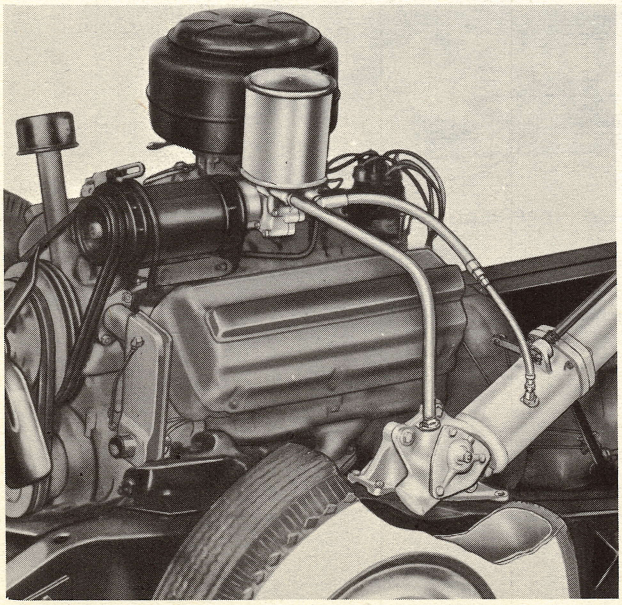


39-37. When a left turn is made, pressure is built up on the opposite side of the piston.

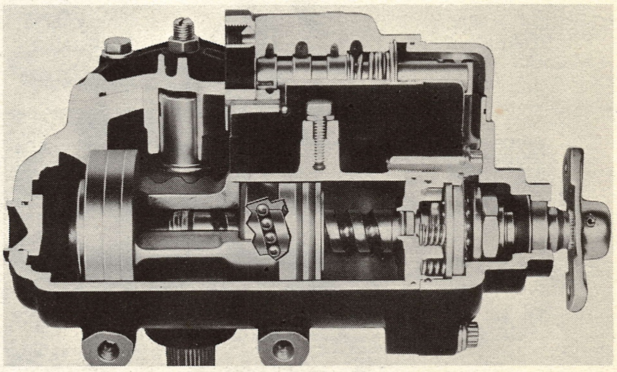
hydraulic type which predominates on automobiles.

In the case of some tractors and military vehicles, the steering is entirely power operated. In general, automobile power steering is actually "power assisted steering." All such automobile systems are so constructed that the car can be steered in the usual manner when the engine is not running or any failure occurs in the power source.

The power steering or "booster" may be built into the steering gear unit, or it may be a separate unit attached to the steering linkage. In the hydraulic type, the pump to supply hydraulic power is belted, geared or otherwise attached to the engine or some driven accessory such as the electric generator. The pump is connected to the steering power unit by piping or hoses with a control valve located at some place in the hydraulic circuit.



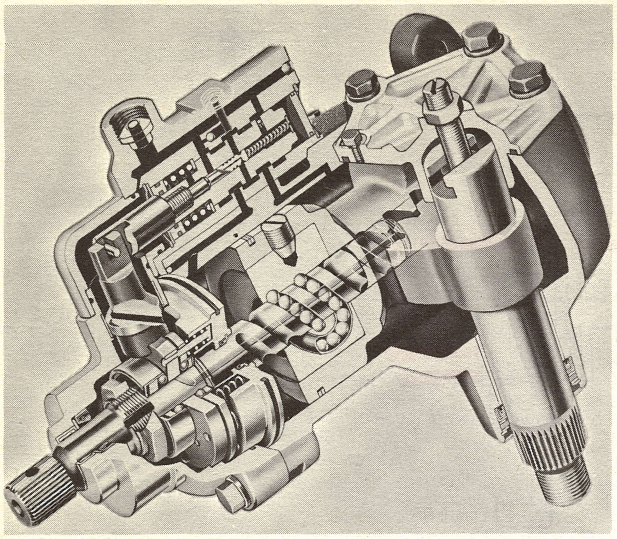
39-38. In this integral power steering installation, the hydraulic pump is located on the end of the generator and is driven by an extension of the armature shaft.



39-39. One model of Saginaw (GMC) integral power steering unit using recirculating balls on the worm shaft.

The construction and operation of hydraulic pumps, control valves and pressure cylinders of the same type used in power steering is covered thoroughly in the transmission section of this text. Therefore in this section we shall not go into detail with such devices, but will be concerned with the construction and operation of the actual steering gears.

There are many makes and types of power steering and there are sometimes multiple models of a make or type. It is therefore im-



39-40. *Cut-away of Cadillac integral power steering showing gear rack as used with recirculating balls.*

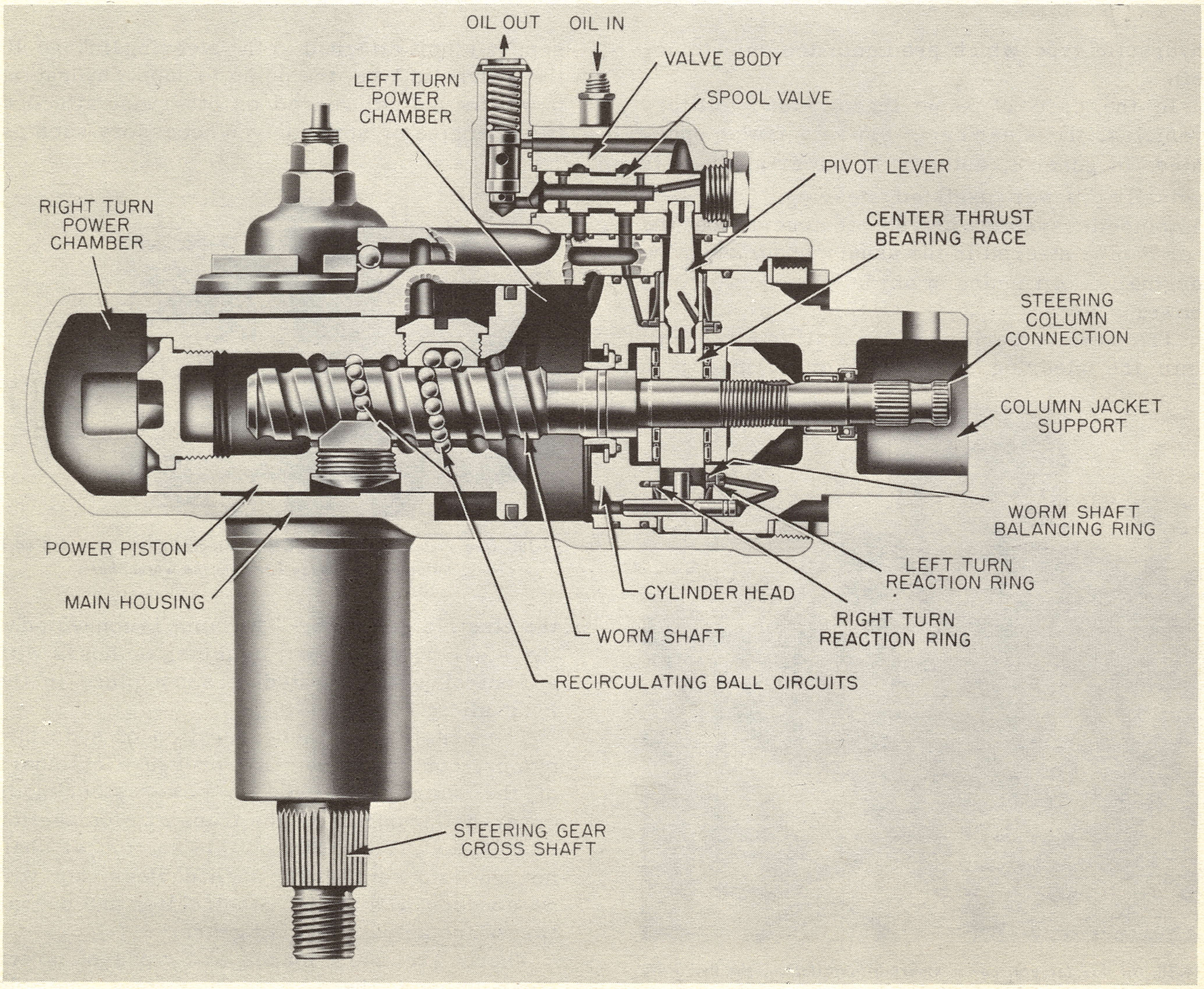
practical to cover other than the general construction and operation of representative systems.

LINKAGE TYPE

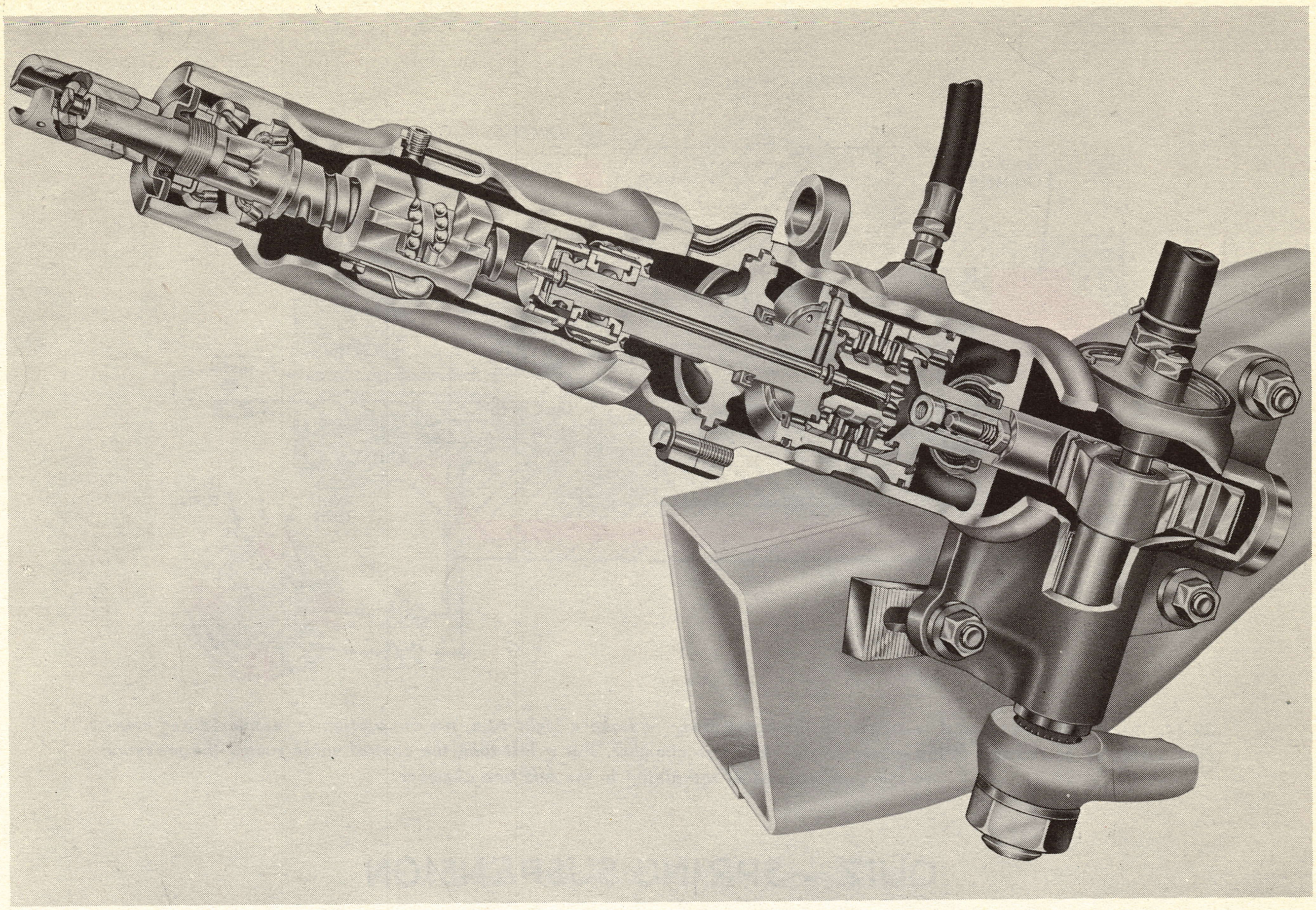
Several types of linkage installations are available. Some of them have the power cylinder separate from the control valve as shown in Fig. 39-31. Others have the control valve integral with the power cylinder as shown in Figs. 39-32 and 39-33.

There are several methods of installing these units in the linkage between the steering gear unit and the road wheels. See Fig. 39-34. Some of the power units have a single cylinder with a piston which acts in both directions, while others have two cylinders and two pistons as shown in Fig. 39-33.

The operation of these devices is quite simple


OIL OUT
OIL IN
VALVE BODY
LEFT TURN POWER CHAMBER
SPOOL VALVE
PIVOT LEVER
RIGHT TURN POWER CHAMBER
CENTER THRUST BEARING RACE
STEERING COLUMN CONNECTION
COLUMN JACKET SUPPORT
WORM SHAFT BALANCING RING
POWER PISTON
LEFT TURN REACTION RING
MAIN HOUSING
CYLINDER HEAD
RIGHT TURN REACTION RING
WORM SHAFT
RECIRCULATING BALL CIRCUITS
STEERING GEAR CROSS SHAFT

39-41. *One type of Chrysler products integral power steering unit showing details of control valves.*



39-42. Power steering of the integral type used by Chrysler and known as "Coaxial Power Steering."

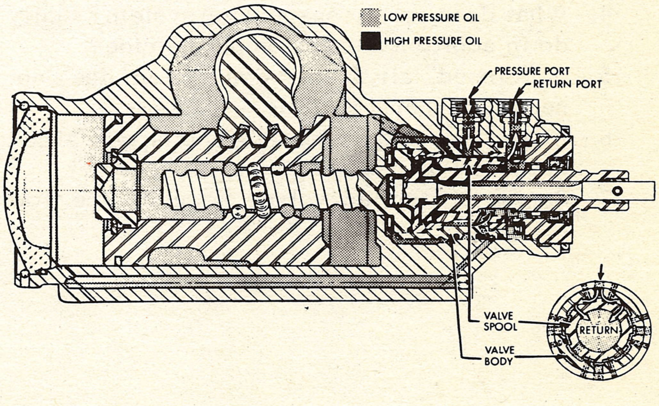
as shown by the diagrams, Figs. 39-35, 39-36 and 39-37. Movement of the steering wheel in either direction actuates a valve which routes the hydraulic pressure to the power cylinder or cylinders which moves the linkage.

INTEGRAL TYPE

Where the power cylinder and control valves are built into the steering gear unit, one of the basic gear designs is often used with alterations to permit power application. Several integral types are shown in Figs. 39-38 to 39-42 incl.

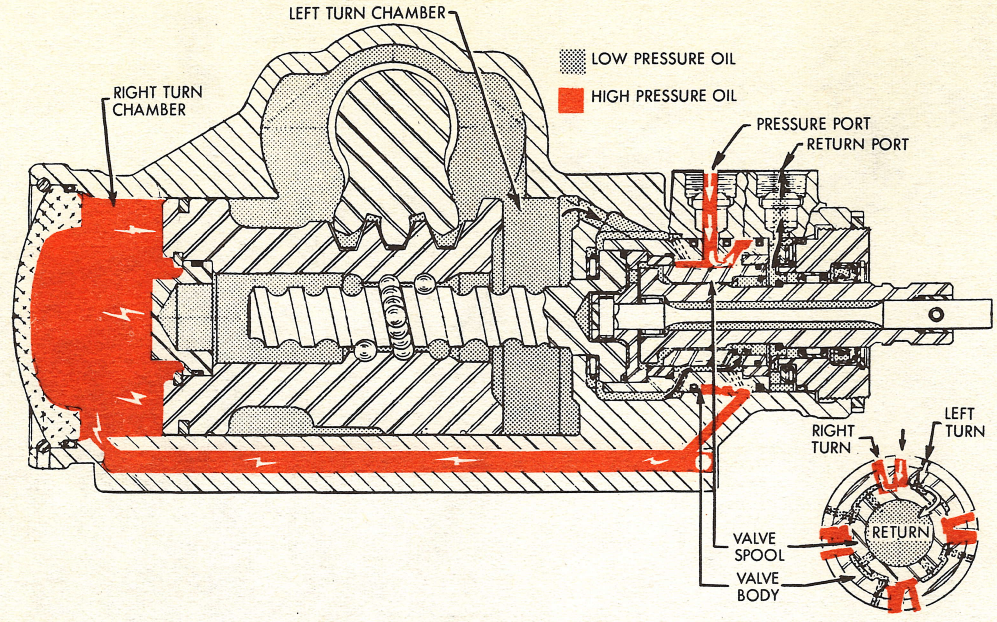
Using one model of a Saginaw gear as an example of operation, we see from Fig. 39-43 that in the straight ahead position, the oil is circulating at low pressure throughout the steering gear unit. The entire unit is full of hydraulic fluid at all times but in the straight ahead position the oil pressure is the same on each side of the piston. Therefore the piston is balanced and no movement occurs.

Turning the steering wheel to make a right turn will change the register of the valve ports in the rotary type valve as shown in Fig. 39-44. As circulation is thus restricted, pressure will build up in the right turn chamber and move the piston. Movement of the piston of course turns the shaft to which the Pitman arm is attached and turns the road wheels.



39-43. In the straight ahead position, the oil is circulating throughout the gear at low pressure as the valve parts are open in this Saginaw unit.

When a left turn is made, the valve will direct the oil to the left turn chamber and the pressure in the right turn chamber will drop to normal.


LEFT TURN CHAMBER
RIGHT TURN CHAMBER
▨ LOW PRESSURE OIL
🟥 HIGH PRESSURE OIL
PRESSURE PORT
RETURN PORT
RIGHT TURN
LEFT TURN
RETURN
VALVE SPOOL
VALVE BODY

39-44. When the valve spool is turned in the valve body to make a right turn, the circulation is restricted and pressure builds up on the end of the piston in the right turn chamber. For a left turn, the control valve routes the pressure to the opposite end of the piston in the left turn chamber.

QUIZ - SPRING SUSPENSION

1. When leaf springs are mounted parallel with the frame for the rear suspension, what other purposes do they serve?
2. Radius rods are usually needed when coil springs are used in the rear suspension. True---, false---.
3. Describe a torsion bar in one sentence.
4. What does an air suspension system usually do in addition to cushioning the ride?
5. A "closed" air suspension system does not need a condenser. True---, false---.
6. In what manner may a telescoping type shock absorber be used to reduce side sway?
7. Spring controlled valves regulate the flow of hydraulic fluid through the shock absorber piston. True---, false---.
8. Give three reasons why power steering is used.
9. Power steering is often only a "booster" or assist in steering. True---, false---.
10. Power steering must be built into a special type steering gear unit. True---, false---.
11. Power steering can operate in both directions with a single piston and cylinder. True-- , false---.
12. What is a "balanced" piston in a power steering system

WHEEL ALIGNMENT CORRECTION

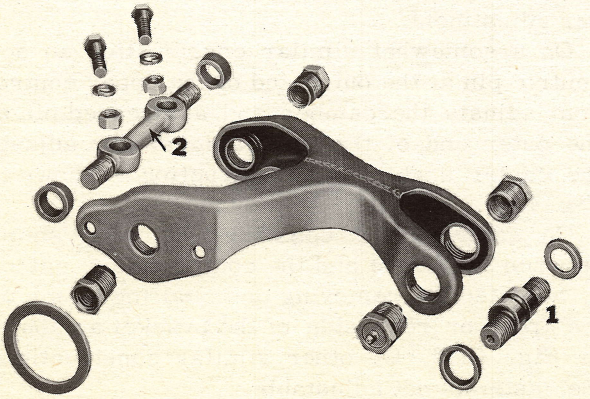
IMPORTANCE OF THEORY

It must always be kept in mind that we must make the adjustments on a stationary vehicle, but we are trying to attain correct conditions on a moving vehicle. An empty car on the alignment equipment is one thing. A loaded car on the road is an entirely different thing. That is why we stress the theory of wheel alignment in this text. The operator must know WHY he is doing various things.

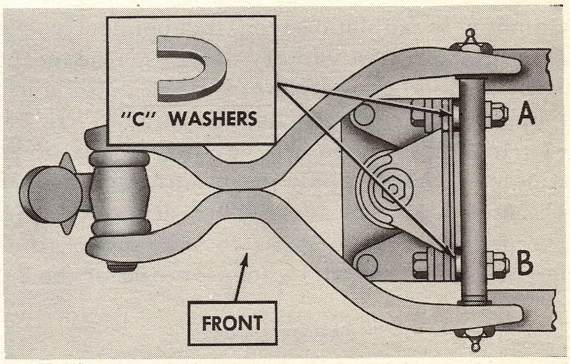
A thorough understanding of the principles involved and enough imagination to visualize actual operating conditions are absolutely essential if the serviceman is to be successful in correcting alignment troubles. Steering troubles, like many other automobile ills, are seldom due to any one defect. They are almost always a combination of several minor defects which add up to more serious trouble.

COMBINATIONS OF ERRORS

For example, a slightly bent steering arm on one side, a fraction of a degree incorrect camber on the other side, a slightly under-inflated tire on one front wheel and a weak front spring on the other side, a defective rear shock absorber on one side and an out of balance rear wheel on the other side might all add up to trouble. Any other combination of defects could be cited. The point is that one of these difficulties would not cause serious trouble, but in combination they become serious. The serviceman therefore must possess the knowledge and mental ability to visualize or see the entire picture at one time.



40-1. The threaded, eccentric pin (1) at the outer end of the upper support arm adjusts camber and caster. The inner pin (2) can be turned over to extend the range of adjustment.



40-2. In this construction, shims in the form of "C" washers are used between the frame and inner end of the upper control arm to regulate the camber angle.

Knowledge and brains are not all that is required. The serviceman must have and know how to use equipment of outstanding accuracy. For example; camber is measured in degrees and minutes. It is measured at a point near the center and therefore the angles become rather fine.

Suppose you have a pie the size of the car wheel. In order to cut it in degrees you will have to cut it into 360 equal pieces. One quarter of one degree (often used in specifications) would mean cutting the pie into 1440 pieces. The pieces in this case would be rather small at the inner end.

We must therefore have accurate equipment, it must be in good condition, it must be carefully used and carefully read.

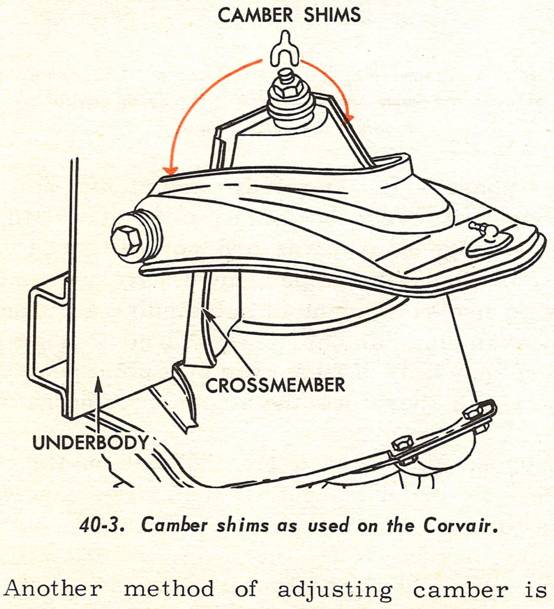
METHODS OF ADJUSTMENT

Before considering the adjustment of the various steering angles, we remind the reader that changing one angle will often change other angles and it is necessary to keep this in mind at all times. It is also necessary to recheck the other angles when one is changed. This means that considerable tedious rechecking in some cases cannot be avoided.

CAMBER ADJUSTMENT

As the camber angle is built into the spindle of solid axle types it is necessary to bend or replace the spindle if the camber angle is incorrect. Replacement is more desirable than bending as previously explained. It is possible to bend the solid axle to correct slight errors in king pin inclination which is built into the axle. Remember that such bending will also change the camber angle of the spindle with relation to the road surface.

Camber is adjustable on independently suspended models in a variety of ways. One method is the threaded eccentric pin in the outer end of the upper control arm as shown at "1" in Fig. 40-1. In some cases where this range of adjustment is insufficient, the pin at the inner end of the upper control arm ("2" in Fig. 40-1) may be turned over. The holes in such upper, inner pins are offset from the center line of the pin.

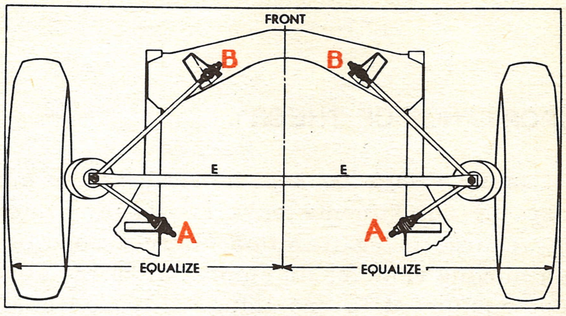


40-3. Camber shims as used on the Corvair.

Another method of adjusting camber is by means of shims placed between the frame and the inner end of the upper control arm. Some typical constructions are shown in Figs. 40-2 and 40-3.

In all the foregoing types the camber is independently adjusted on each wheel. In one type of front suspension shown in Fig. 40-4, however, an increase in camber on one wheel will automatically decrease the camber in the other wheel as both spindles are attached to a cross bar at the top.

In some cases caster and camber adjustments are combined at a single point as explained in the following text.



40-4. Shorten long rods and lengthen short rods to decrease caster. Lengthen long rods and shorten short rods to increase caster. Lengthen both right-hand rods and shorten both left-hand rods to increase right camber. Shorten both right-hand rods and lengthen both left-hand rods to decrease right camber. NOTE: One and one-half complete turns of the nuts at "A" and "B" are equal to approximately ¼ deg.

CASTER ADJUSTMENT

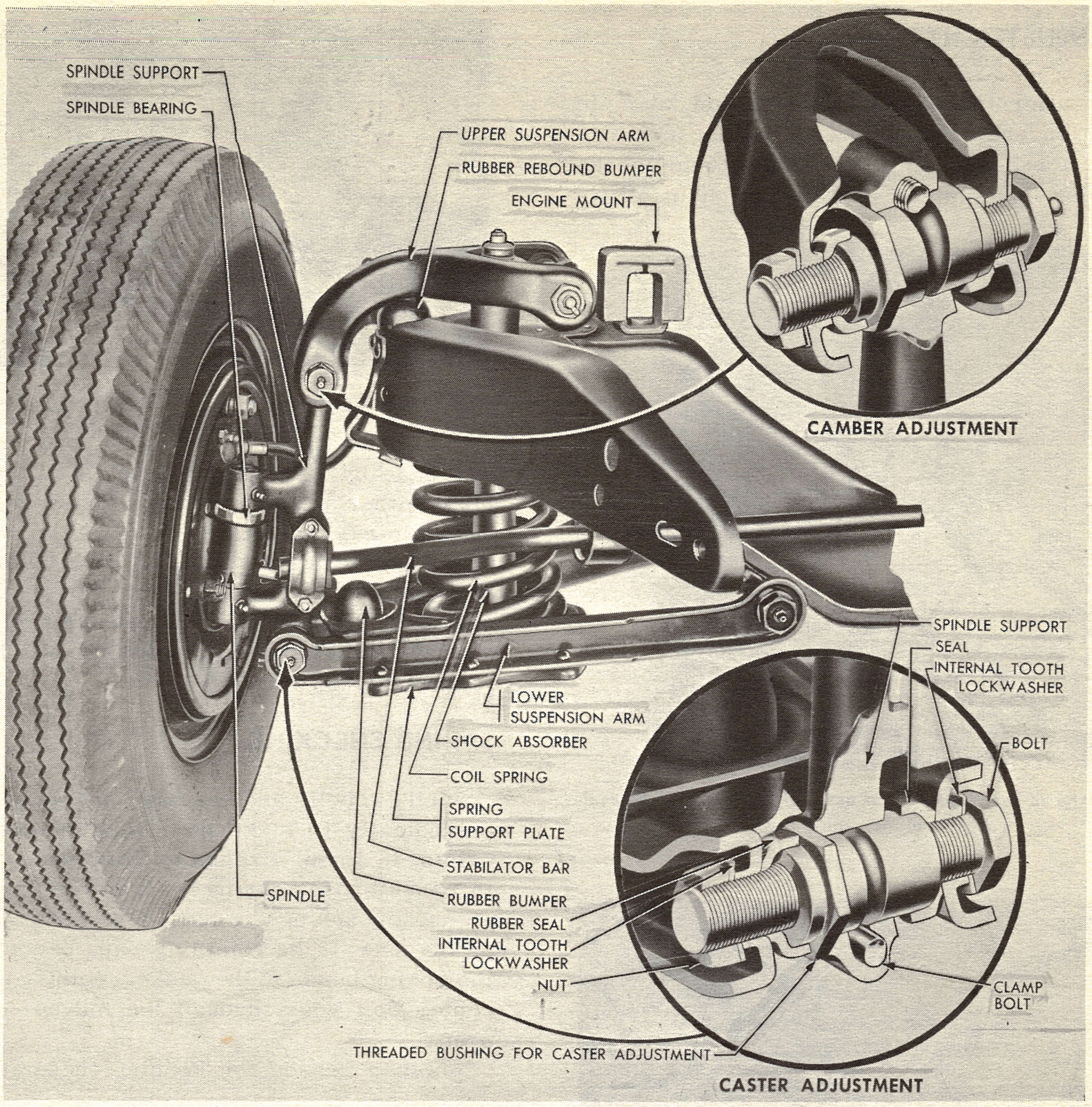
On the solid type axle, caster can be altered by inserting tapered wedges between the axle and spring on longitudinal springs, and by means of the radius rods where transverse springs are used.

In the case shown in Fig. 40-1, a complete revolution of the pin changes the caster. After the caster is adjusted as required by one or more turns of the pin, the camber is then adjusted with the same pin which is eccentric. One half turn of the pin covers the range of the camber adjustment.

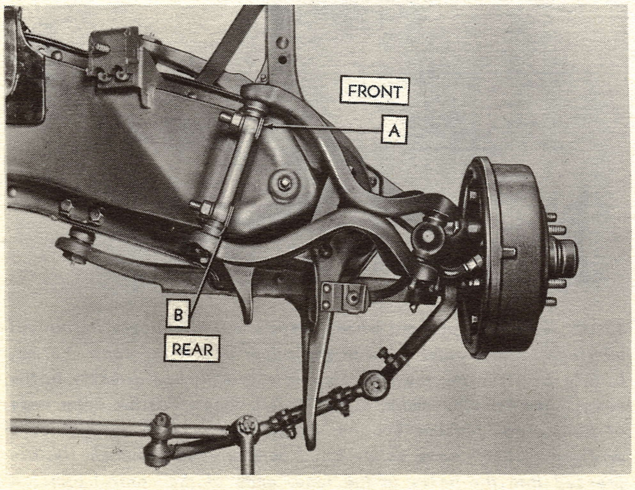
On a somewhat similar construction an eccentric pin at the outer end of the upper control arm adjusts the camber and a threaded pin at the outer end of the lower control arm adjusts the caster angle. This construction is shown in Fig. 40-5.

On some of the constructions using shims between the frame and the control arms, caster is adjusted by removing or installing shims on the front or rear side of the bracket as shown in Fig. 40-6. On other similar constructions the caster is not adjustable.

In the construction shown in Fig. 40-4 the caster is adjusted by shortening and lengthening the angular rods on each side. The same method


SPINDLE SUPPORT
SPINDLE BEARING
UPPER SUSPENSION ARM
RUBBER REBOUND BUMPER
ENGINE MOUNT
CAMBER ADJUSTMENT
SPINDLE SUPPORT
SEAL
INTERNAL TOOTH LOCKWASHER
BOLT
LOWER SUSPENSION ARM
SHOCK ABSORBER
COIL SPRING
SPRING SUPPORT PLATE
STABILATOR BAR
SPINDLE
RUBBER BUMPER
RUBBER SEAL
INTERNAL TOOTH LOCKWASHER
NUT
CLAMP BOLT
THREADED BUSHING FOR CASTER ADJUSTMENT
CASTER ADJUSTMENT

40-5. In this case the camber is adjusted by means of an eccentric pin in the outer end of the upper control arm and caster is adjusted by means of a threaded pin in the outer end of the lower control arm.


FRONT
A
B
REAR

40-6. Caster is regulated by the insertion or removal of shims at either the front or rear as required.

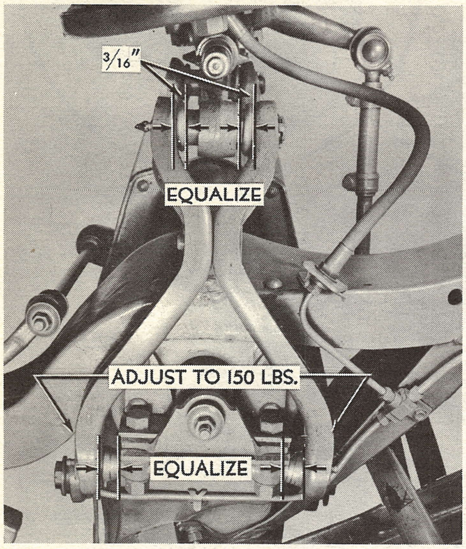
is used to adjust caster on the Corvair and others using strut rods attached to the suspension.

On those models on which no adjustment is provided for the caster angle, the steering spindle is positioned in the control arm at the time of assembly to provide the desired caster angle. See Fig. 40-7. Also see Figs. 40-8, 9, 10, 11. Additional information on caster and camber adjustment is found later herein under torsion bars.

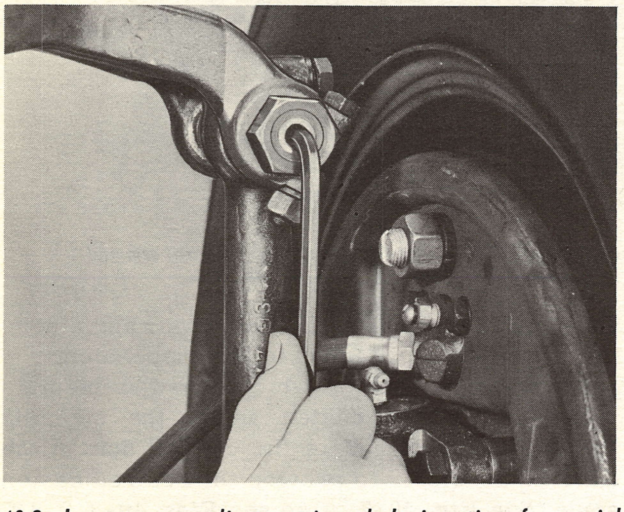
It will be noted on many independently suspended axles that the control arms are mounted at an angle from horizontal. See Fig. 40-12. This is for the purpose of reducing front end dip and rear end rise when the brakes are applied and some of the car weight transfers from rear to front. This weight transfer is covered in the brake section of this text.

TOE ADJUSTMENT

Only after the caster, camber and king pin inclination angles have been checked and corrected if necessary is it possible to adjust the tie rods. This is the last operation in alignment procedure. The methods of adjustment have been previously described herein.

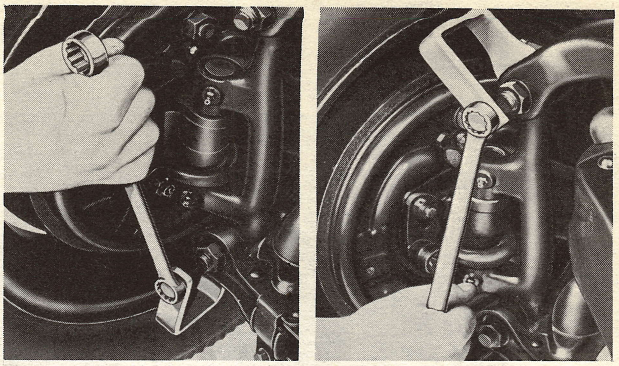


40-7. *Caster is set at the time of assembly in this case by positioning of the control arm.*



40-8. *In some cases adjustment is made by insertion of a special wrench after removal of the grease fitting in the end of the pin.*

Where independently suspended rear wheels are used with a swing axle, the toe of the rear wheels should be checked. In the case of the Volkswagen, the toe may be in or out. In either case it is important that each wheel toes in or toes out to the same degree. The most desirable condition is a toe-out of 0.08 in. Correction can be made by enlarging the holes in the spring plate either to the rear or to the front. This is shown in Fig. 40-13.



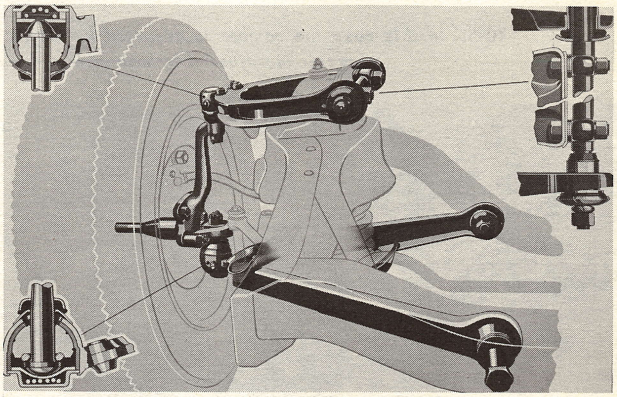
40-9. *Special offset wrenches are used to adjust camber and caster in this construction.*

In the Corvair a slight toe-in is desired. Toe is adjusted by installing or removing shims as shown in Fig. 40-14. Both wheels are adjusted at once therefore shims must be added or subtracted equally on each side.

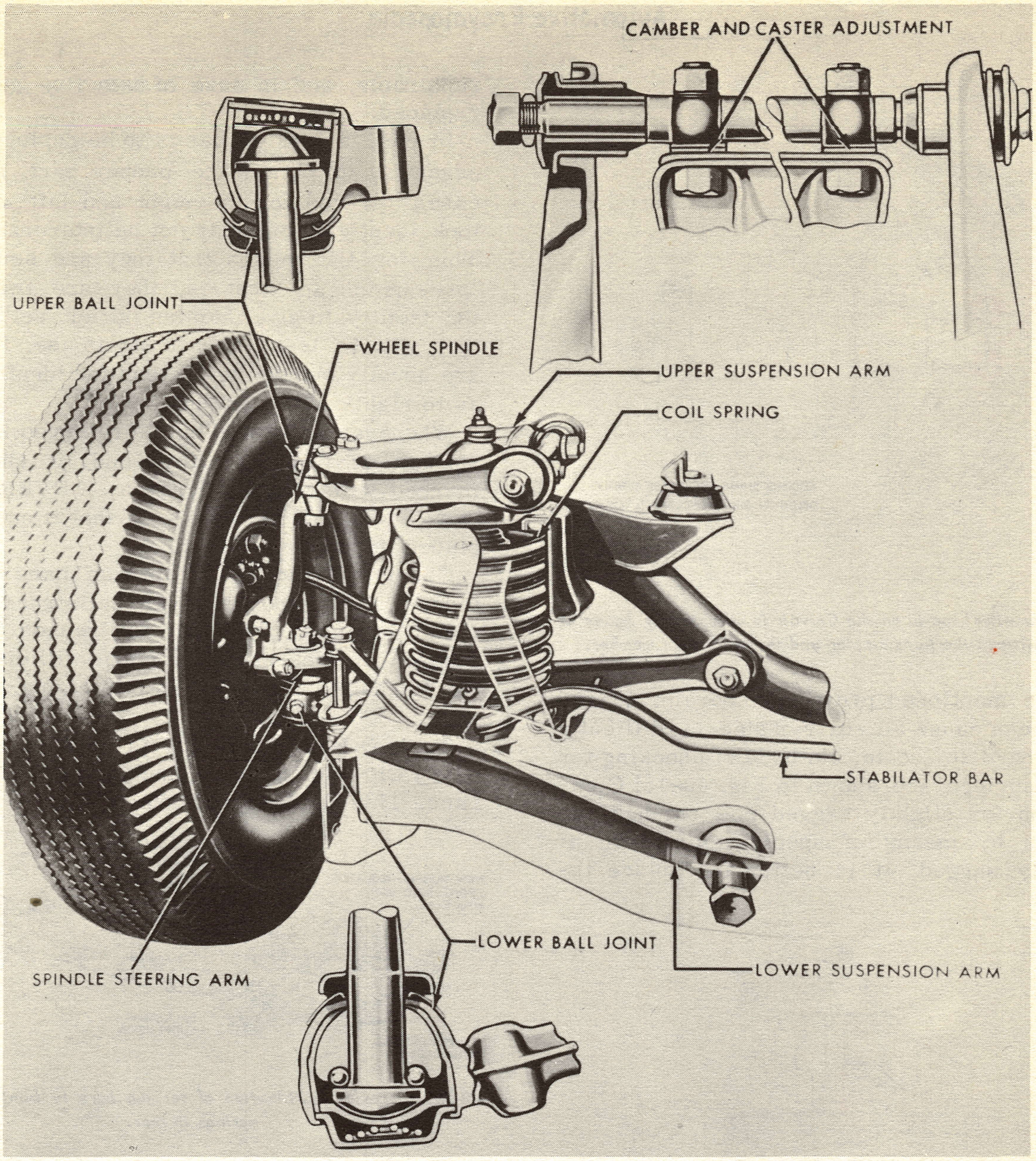
SPRING CHECKING

Springs, bolts and shackles should be checked periodically to make sure that no excess wear exists in them. Excessive looseness is liable to cause broken spring leaves. The usual cause of broken springs is looseness in the mounting on the axle. If the retaining clips become loose, the spring bends at the weakest point---where the center bolt goes through the leaves---and may break.

Another reason for keeping these clips tight



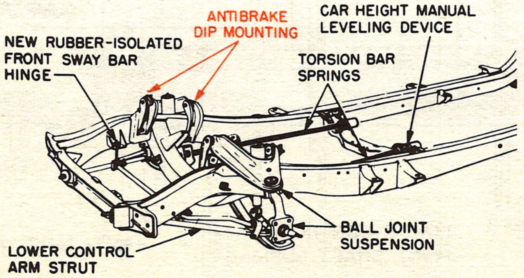
40-10. *This type of front wheel suspension eliminates individual bearings for the outer ends of the upper and lower control arms. In this construction the wheel spindle is attached directly to the suspension arms by means of ball joints located at the outer ends of both arms. Rubber bushing assemblies, which consist of a moulded rubber sleeve sandwiched between two steel shells, are pressed into the holes in the inner ends of the control arms. A cup type washer is used to lock each bushing inner shell so that all pivoting of these joints occurs by flexing of the rubber.*


CAMBER AND CASTER ADJUSTMENT
UPPER BALL JOINT
WHEEL SPINDLE
UPPER SUSPENSION ARM
COIL SPRING
STABILATOR BAR
LOWER BALL JOINT
SPINDLE STEERING ARM
LOWER SUSPENSION ARM

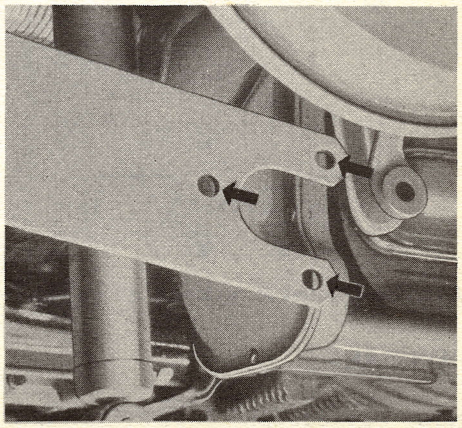
40-11. The adjustments for wheel caster and camber are made at the upper suspension arm inner shaft, and are accomplished by installing or removing shims from between the inner shaft and the frame.

is to prevent shifting of the axle. If the center bolt is loose or broken, the axle can move backward or forward and disrupt the wheel alignment as explained previously in this text.

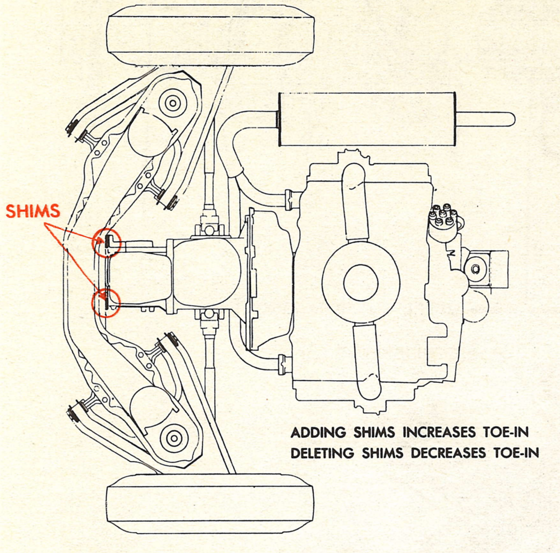
The need for spring balance and load equality


NEW RUBBER-ISOLATED FRONT SWAY BAR HINGE
ANTIBRAKE DIP MOUNTING
CAR HEIGHT MANUAL LEVELING DEVICE
TORSION BAR SPRINGS
BALL JOINT SUSPENSION
LOWER CONTROL ARM STRUT

40-12. One method of reducing front end dip is to mount the front control arm brackets to lean backward at the top.

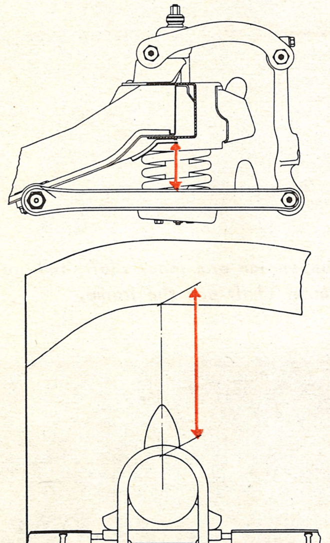


40-13. Holes in spring plate which can be enlarged to help correct rear wheel alignment.


SHIMS
ADDING SHIMS INCREASES TOE-IN
DELETING SHIMS DECREASES TOE-IN

40-14. Rear wheel toe-in on the Corvair is adjusted by means of shims between the transmission and the rear cross member.

has been mentioned previously herein. Sagged springs can cause all sorts of steering difficulty that is hard to locate. Methods of checking for sagged springs are shown in Fig. 40-15. Compensation for slightly sagged coil springs can be made by means of special shims, but if seriously sagged, it is better to replace the spring.



40-15. Usual points of measurement for spring sag.

TORSION BARS

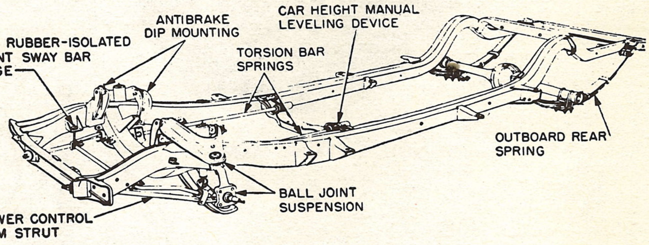
Torsion bar suspension has proved to be remarkably free from service troubles, particularly the bars themselves. These bars are not repairable, and in case of defective action are replaced.

In case a torsion bar is to be replaced, it is essential to obtain the proper part. In many cases the rod for the right and left side may look identical, but may not be interchangeable. This for the reason that they are sometimes "pre-stressed," that is, they are twisted at the factory to give them an initial "set" so that they will be less liable to sag in use. The bars are usually marked on the end for identification as to right or left side use.

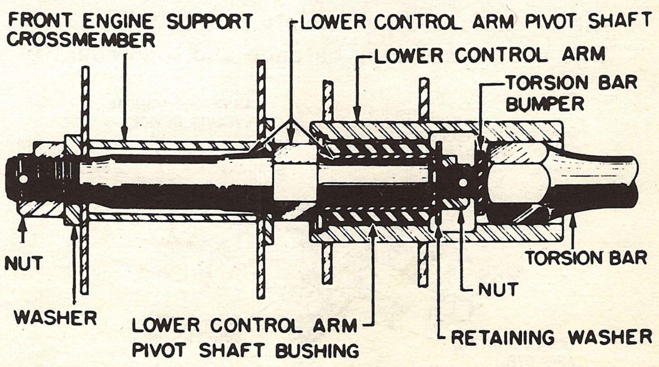
Whenever a torsion bar is removed from the splines or flats at either end, it should be marked with chalk or crayon---NEVER FILED OR CENTER PUNCHED---so that it can be replaced in proper position.

Careless handling of torsion bars is forbidden. They should never be struck with a metal hammer. This for the reason that any scratch or nick on the surface will encourage the formation of a crack in this highly stressed part.

Torsion bar suspension is used on the front of all Chrysler built automobiles at the present time. This design is shown in Fig. 40-16. The front ends of the torsion bars are anchored in the control arms as shown in Fig. 40-17. The rear ends of the bars are anchored at the frame in a bracket which provides a means of adjusting the tension on the bar to keep the car level. See


NEW RUBBER-ISOLATED FRONT SWAY BAR HINGE
ANTIBRAKE DIP MOUNTING
CAR HEIGHT MANUAL LEVELING DEVICE
TORSION BAR SPRINGS
OUTBOARD REAR SPRING
BALL JOINT SUSPENSION
LOWER CONTROL ARM STRUT

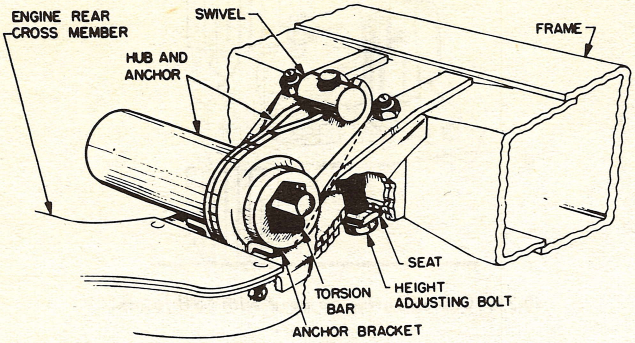
40-16. Chrysler combination of torsion bars in front with leaf springs in rear.


FRONT ENGINE SUPPORT CROSSMEMBER
LOWER CONTROL ARM PIVOT SHAFT
LOWER CONTROL ARM
TORSION BAR BUMPER
NUT
TORSION BAR
WASHER
LOWER CONTROL ARM PIVOT SHAFT BUSHING
NUT
RETAINING WASHER

40-17. One hexagonal end of the torque bar fits in a hex shaped hole in the control arm.

Fig. 40-18. The weight of the car must be removed from the bars before any attempt is made at adjustment by means of the screw provided.

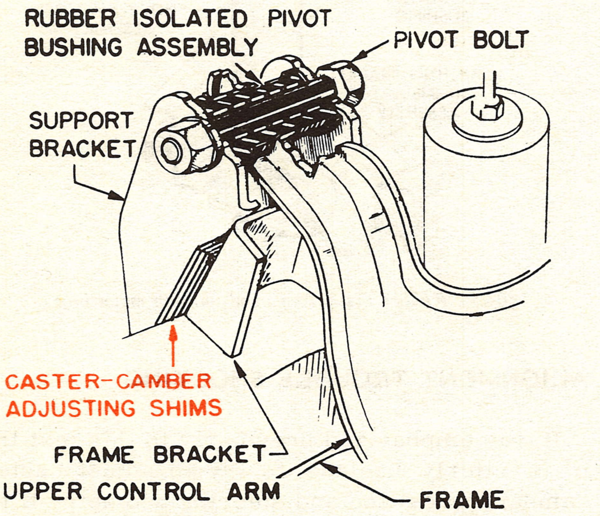
Caster and camber angles are adjusted on earlier models by the removal or addition of shims between a frame bracket and the support arms as shown in Fig. 40-19. On later models a cam adjustment device is provided. See Fig. 40-20.


ENGINE REAR CROSS MEMBER
SWIVEL
HUB AND ANCHOR
FRAME
SEAT
TORSION BAR
HEIGHT ADJUSTING BOLT
ANCHOR BRACKET

40-18. Method of adjusting Chrysler torsion bars.

There are no adjustments provided on the torsion bars as used by Packard as the levelizer takes care of load and height variations.

Camber and caster angles are not adjustable on the Volkswagen construction and therefore any errors in wheel alignment angles indicate the need for new parts. It is of course essential before making any alignment checks to make certain that no excess wear or looseness exists in any part of the front suspension system.

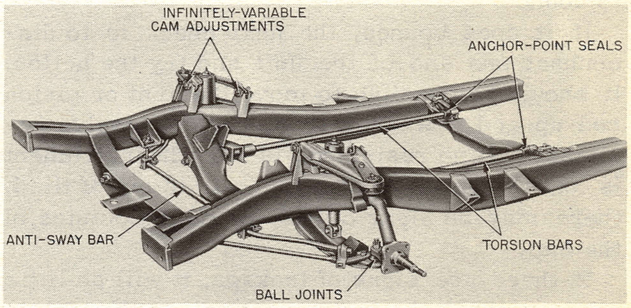

RUBBER ISOLATED PIVOT BUSHING ASSEMBLY
PIVOT BOLT
SUPPORT BRACKET
CASTER-CAMBER ADJUSTING SHIMS
FRAME BRACKET
UPPER CONTROL ARM
FRAME

40-19. Earlier Chrysler models used a shim pack for caster and camber adjustment.

Compensation for sagging or heavy loading can be made at the rear torsion bars by means of the splines on each end. To make a fine adjustment possible, the inner end of the bar has 40 splines while the outer end has 44 splines. Turning the bar one spline at the inner end will make a change of 9 deg. One spline at the outer end will make a change of 8 deg. and 10 min.

It is essential that any such adjustment should result in the angle on both sides being the same. It should also be borne in mind that excessive raising or lowering of the rear end will affect the caster angle of the front axle.

Any steering difficulty with any automobile will multiply as the speed of the car increases due to wheel bounce. Obviously, the tire must remain in contact with the road surface if the car is to be steered by the front wheels. Spring rebound is in proportion to the speed and amount of spring deflection required to absorb road shocks. Therefore shock absorbers must operate effectively.


INFINITELY-VARIABLE CAM ADJUSTMENTS
ANCHOR-POINT SEALS
ANTI-SWAY BAR
TORSION BARS
BALL JOINTS

40-20. Later Chrysler models had an infinitely variable cam adjustment for caster and camber angles.

SHOCK ABSORBER CHECKING

Shock absorbers are ordinarily one of the most neglected parts of an automobile, and are often blamed for faults in other parts of the car. They are neglected because they are under the car out of sight and also because deterioration in action is so gradual as to be unnoticed. Springs and shackles are neglected for the same reason.

Before repairs or adjustments are attempted on shock absorbers, it is important to make sure that the car springs are not broken or caked with mud and rust. The shackles should be free and properly lubricated unless they are of the rubber mounted type. Even the rubber mounted type require lubrication with special rubber lubricant once in a while to avoid annoying squeaks.

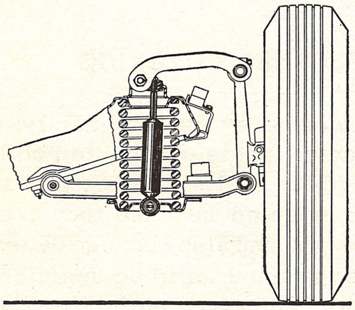
Any dryness in the spring bolts or shackles, or binding in the shackles will interfere with proper action and will encourage breakage of leaf springs. Sometimes the shackles are drawn up so tightly that they pinch the sides of the spring eye or mounting bracket.

Tire inflation and condition should also be checked. An old tire with a flat tread will ride harder than a new tire. A six-ply tire will ride harder than a four-ply tire. An undersize tire will require higher air pressure to support the load and will thus ride harder.

If the tires are of the correct type and size and in reasonably good condition, the springs and shackles properly lubricated and adjusted, the shock absorbers are then to be considered. The usual quick, preliminary test is to grasp the bumper firmly and bounce the car up and down. If the shock absorbers are functioning correctly the car will not bounce very well. It can be moved up and down but will not continue to bounce.

If it does bounce, the next check is to disconnect one end of the unit and try the action. It should be possible to move the arm or piston rod up and down slowly without excessive resistance. If no resistance is felt, the instrument is out of fluid or faulty. If it is out of fluid, there may be signs of leakage on the outside of the unit.

If there are signs of leakage, it will do little good to refill the instrument unless the leak is repaired. Pressures are quite high within the shock absorber and the fluid will be forced through the smallest opening in the cylinder or around the shaft. Repair usually requires removal of the unit. In many cases the unit is not repairable in the average service station and is therefore replaced with a new or rebuilt unit.

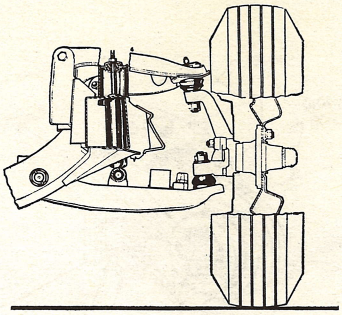


40-21. Shock absorber mounting within front spring.

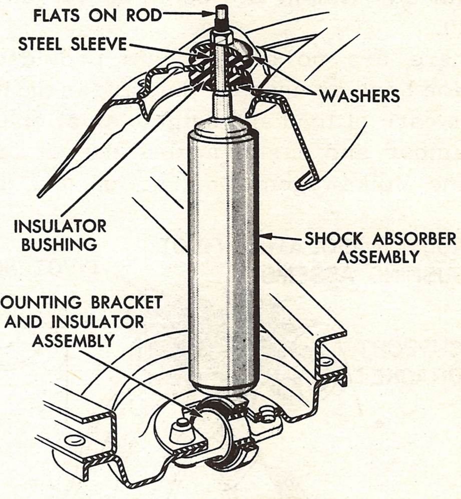
NOISY OPERATION

Quite often the shock absorbers are blamed for noise. The noise may be in the spring shackles, the springs, the sway bar, sway bar mounting or some other place. It can be checked by temporarily disconnecting the shock absorbers and testing the car.

If the noise is proved to be coming from the shock absorber itself, it may be loose on the mounting bolts. See Figs. 40-21 and 40-22. Or the connecting link from the arm to the axle may be worn or loose at the bushings. In the telescoping type the attaching eyes may be worn or loose. See Fig. 40-23. The noise will seldom be found within the shock absorber unit itself.



40-22. One mounting as used with ball joints.



40-23. Rubber insulation used on both mountings.

ALIGNMENT TROUBLE SHOOTING

It was emphasized previously in this text that it is utterly useless to try to adjust caster, camber, wheel toe and steering geometry if the parts are excessively worn. Looseness and sloppy fits cannot be tolerated if satisfactory performance is to be obtained.

There is however one part that may be unjustly condemned. This is the threaded type of pins that are used within threaded bushings in the front system. These pins are not intended to fit tightly in the threads. A brand new set should be quite loose with no weight on them. The design is such that the Vee threads on the pin fits in the Vee threads in the bushing so that the weight of the car holds them tightly together on the thread angle and there is no looseness. See Fig. 40-24.

Aside from worn parts, there are many other difficulties that have been mentioned previously herein. It should be clear to you by now that a careful inspection is in order before you dive into changing caster, camber, etc. You know that unevenly worn tires, out-of-round wheels, unbalanced wheel assemblies, double inner tubes, etc., may cause wheel bounce and interfere with proper tire contact with the road.

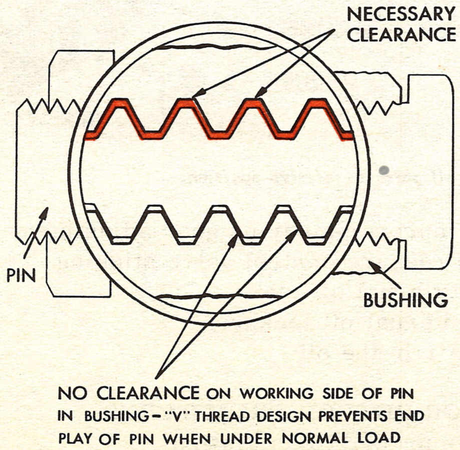
You should understand that defective shock absorbers will permit frequent and excessive changes in steering angles. Springs should be in balance. A sagged or weak spring will unbalance the weight distribution on the wheels with the results previously explained.

In case of a serious sag at one corner of the car, it is well to check for a sagged frame or front cross member. Any sag in the cross member that changes the relative position of the inner ends of the support arms will change camber and king pin angles.

For example, if the frame cross member should sag down in the middle, the upper ends of the spindle arms will be drawn closer together with a consequent lessening of camber. Accumulative wear at the eight pivot points would create a similar condition. If such a condition is aggravated by unequal weight distribution, the result will likely be poor performance.

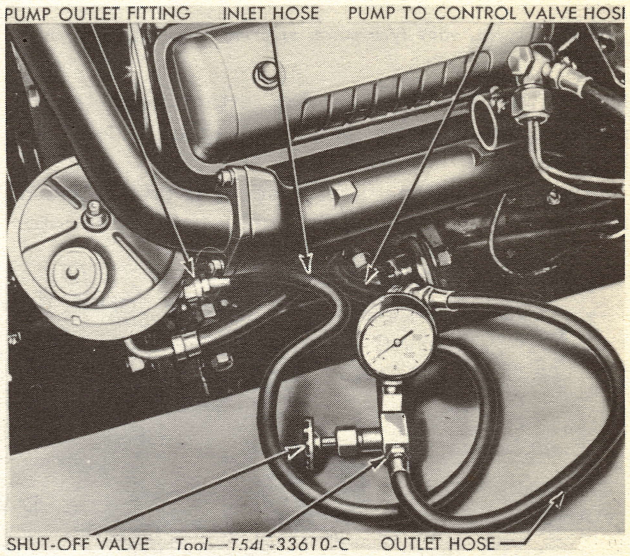
It must be kept in mind that the weight of the entire car and passengers is balanced above the tires and springs, both of which are flexible. This weight not only moves up and down; it can sway sidewise from the action of centrifugal force or wind pressure. It can also move forward and backward from acceleration and braking forces.

There may be more weight on one side of the car than the other because of engine torque reaction on the frame, baggage or goods piled on one side of the body or trunk, the driver being alone in the car, or anything whatever that puts more weight on one side of the car than the other.


NECESSARY CLEARANCE
PIN
BUSHING
NO CLEARANCE ON WORKING SIDE OF PIN IN BUSHING–"V" THREAD DESIGN PREVENTS END PLAY OF PIN WHEN UNDER NORMAL LOAD

40-24. Special threads are designed for clearance.

When trouble shooting automobile handling problems, there is no quick and easy remedy to apply. It is a complicated series of causes and effects which you must be able to think your way through after a thorough study and complete understanding of the underlying theories involved. There are no short cuts.

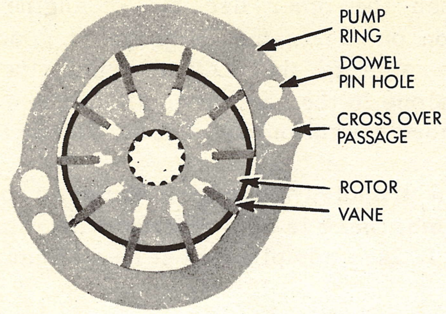


40-25. Typical oil pressure gauge installed in pressure side of line to test hydraulic pressure.

POWER STEERING TROUBLE SHOOTING

Just because a car is equipped with power steering it does not mean that the usual steering and alignment troubles can be ignored. In fact it is all the more important to make sure that the wheels are in proper alignment, tires properly and equally inflated, all parts of the steering system adequately lubricated and no excess wear or looseness at any point. All this for the reason that the power steering may prevent the car driver from being aware of looseness or hard steering, or he may ignore it until serious damage is done.

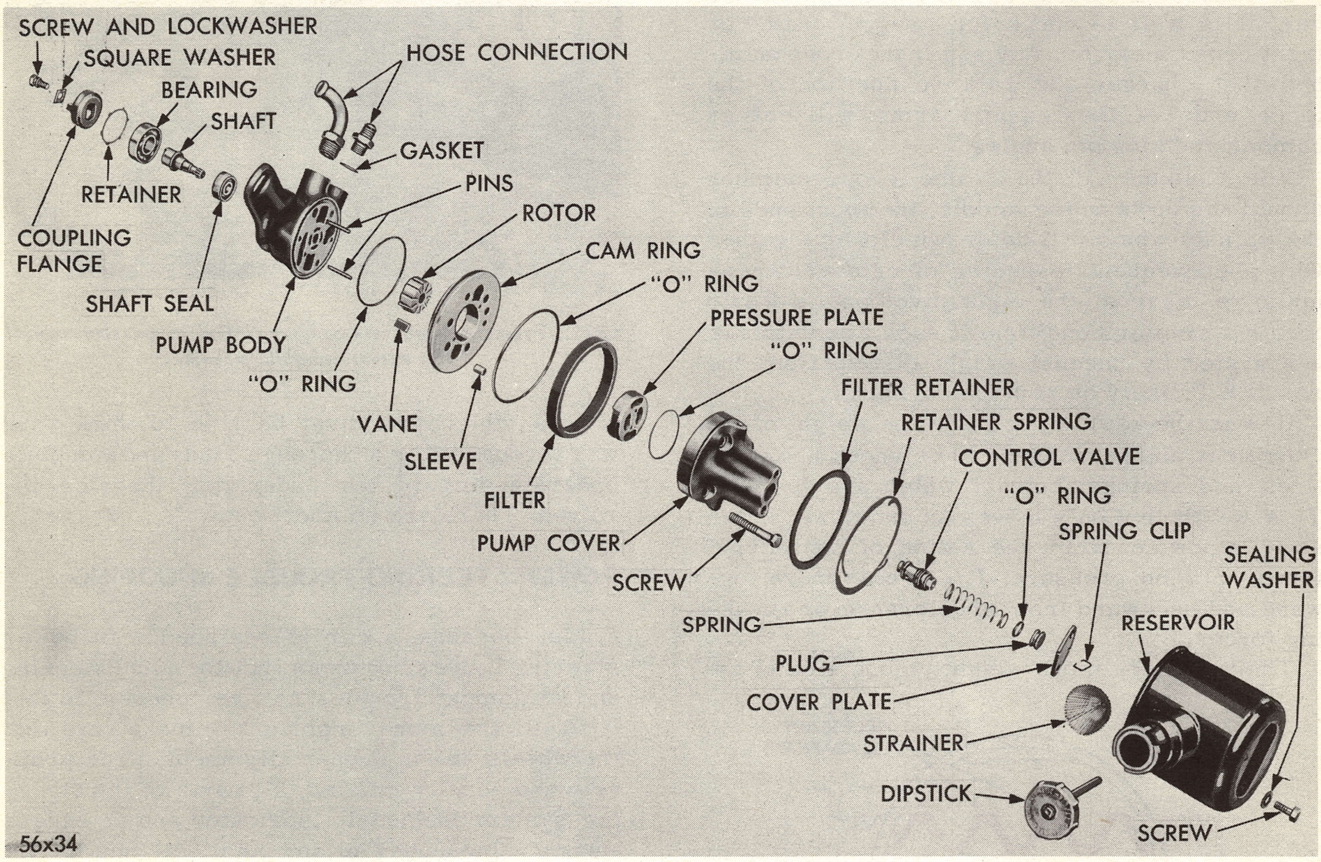
In checking power steering operation, it is necessary to have a suitably calibrated pressure gauge to check hydraulic pressures in the system. These pressures may approach 1,500 lb. per sq. in. in some systems. The return lines do not carry high pressure, and the pressure lines are usually marked or in any case


PUMP RING
DOWEL PIN HOLE
CROSS OVER PASSAGE
ROTOR
VANE

40-26. Typical vane type power steering pump construction.

have different fittings for attachment to the pump and steering gear power cylinder. See Fig. 40-25.

Pressure pumps are of several types, one of the more popular types consisting of a rotor with vanes which operate within a round or oval housing. See Figs. 40-26 and 40-27.


SCREW AND LOCKWASHER
SQUARE WASHER
BEARING
SHAFT
RETAINER
COUPLING FLANGE
SHAFT SEAL
PUMP BODY
HOSE CONNECTION
GASKET
PINS
ROTOR
CAM RING
"O" RING
"O" RING
VANE
SLEEVE
PRESSURE PLATE
"O" RING
FILTER
FILTER RETAINER
RETAINER SPRING
CONTROL VALVE
PUMP COVER
SCREW
"O" RING
SPRING CLIP
SEALING WASHER
SPRING
PLUG
COVER PLATE
RESERVOIR
STRAINER
DIPSTICK
SCREW
56x34

40-27. Exploded view of another vane type pump with all parts in relative position.

When checking oil pressures, the engine and the hydraulic fluid should be at operating temperatures in order to obtain a true reading. Maximum pressure should be generated with the steering wheel held in the extreme turn position.

CAUTION: Do not hold wheel in extreme position for an extended period of time because it will drastically increase the oil temperature and may cause undue wear or damage in the oil pump.

Low pressure in any part of the system may be caused or aggravated by kinks in the hose lines or obstructions or dirt in the lines or fittings.

TROUBLE DIAGNOSIS

1-HARD STEERING
  A-Improper tire inflation
  B-Loose pump belt
  C-Low oil level
  D-Steering linkage needs lubrication
  E-Improper caster or camber
  F-Insufficient pump output
  G-Improper steering gear adjustment
  H-Pressure control valve sticking
  I-External oil leaks
  J-Internal oil leakage
  K-Air in the oil

2-POOR RETURN FROM TURNS
  A-Improper tire inflation
  B-Steering gear linkage binding

C-Improper wheel alignment
D-Pressure control valve sticking
E-Steering gear misalignment
F-Improper steering gear adjustment
G-Internal oil leakage
H-Air in the oil

3-TEMPORARY INCREASE IN EFFORT WHEN TURNING
A-Air in the oil
B-Low oil level
C-Loose pump belt
D-Internal oil leakage
E-Engine idle too low

4-CAR LEADS TO EITHER SIDE
A-Improper or unequal tire inflation
B-Tire tread wear unequal
C-Improper wheel alignment or car balance
D-Defective or improperly adjusted control valve

5-EXCESSIVE STEERING LOOSENESS
A-Improper steering gear adjustment
B-Loose tie rod ends or linkage
C-Air in oil

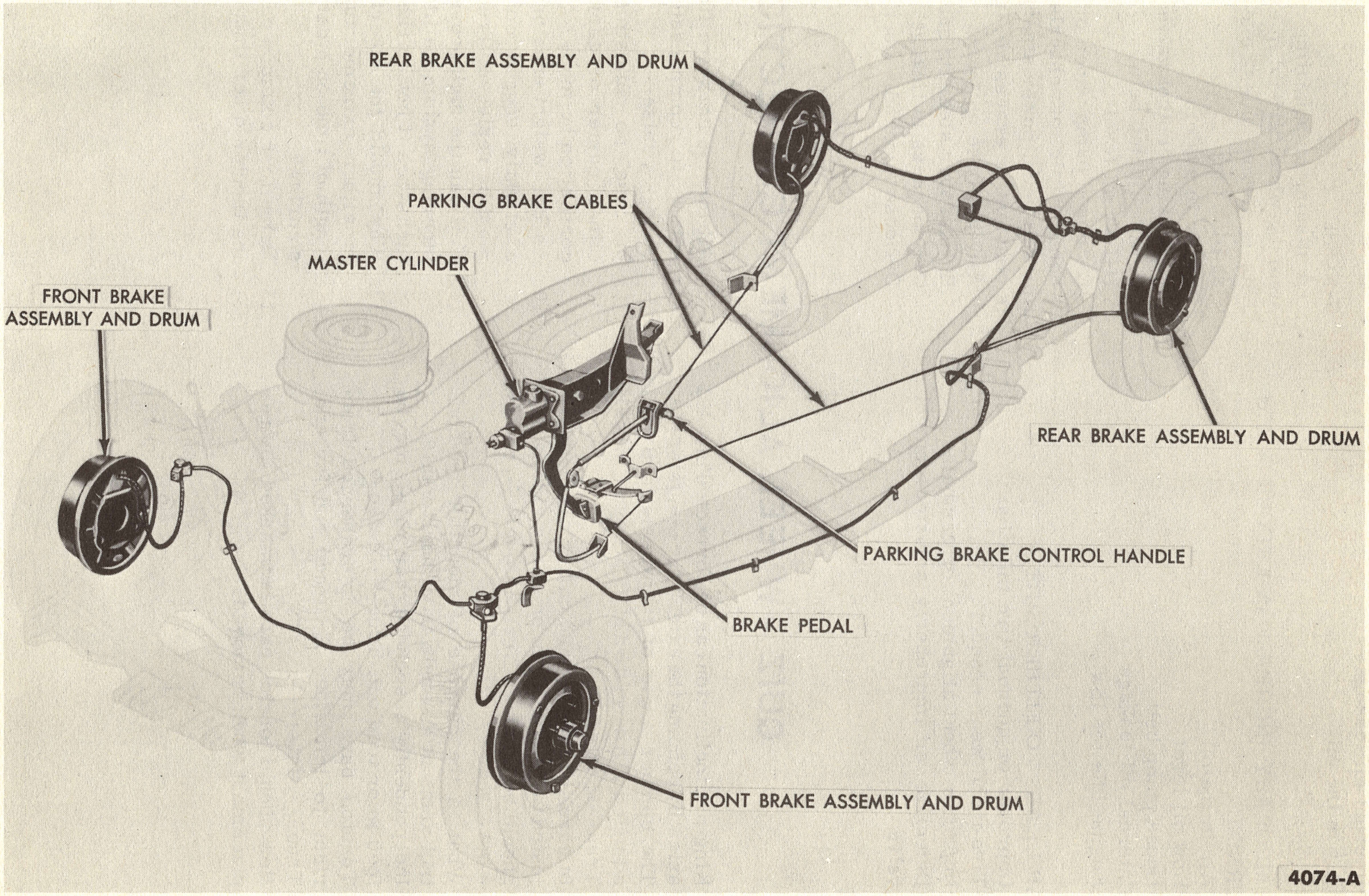
6-NOISE

A hissing or squealing noise may occur when steering wheel is held in extreme turn position. This is normal unless excessively loud. Otherwise look for:
A-Air in system
B-Sticking control valve
C-Loose pump belt
D-Low oil level
E-Scored pump vanes or body

Some rattle or chuckle may be evident at times in most power steering systems. If noise is constant or excessive, look for:
A-Gear loose on frame
B-Improper steering gear adjustment
C-Looseness in linkage
D-Loose shock absorber

QUIZ - WHEEL ALIGNMENT CORRECTION

1. King pin inclination can be corrected in solid axles by bending the axle. True---, false---.
2. The camber angle of the wheels is always adjusted individually at each wheel. True---, false---.
3. In case the camber and caster are both adjusted at a single pin on either side, which should be adjusted first; camber---, caster ---?
4. What is the purpose of mounting the control arms at an angle from horizontal?
5. Independently suspended rear wheels may be toed in or toed out. True---, false---.
6. Torsion bars may be interchanged from right to left sides if turned end for end. True---, false---.
7. How should torsion bars be marked for replacement when removed?
8. All torsion bars are fitted with an adjusting screw to compensate for possible sag. True---, false---.
9. In case no adjustment is provided for either caster or camber angles, how can correction be made?
10. As car weight unbalance may be caused by a slightly sagged coil spring, the spring must be replaced. True---, false---.
11. How can the high pressure lines of a power steering system be identified from the return lines if not marked?
12. Why should the steering wheel not be held in either extreme turn position for any length of time on a car equipped with power steering?
13. Name four common causes of power steering trouble other than oil leakage.


REAR BRAKE ASSEMBLY AND DRUM
PARKING BRAKE CABLES
MASTER CYLINDER
FRONT BRAKE ASSEMBLY AND DRUM
REAR BRAKE ASSEMBLY AND DRUM
PARKING BRAKE CONTROL HANDLE
BRAKE PEDAL
FRONT BRAKE ASSEMBLY AND DRUM
4074-A

41-1. Layout of modern hydraulic brake system.

AUTOMOTIVE BRAKES

An automotive brake, Fig. 41-1, is a friction device which changes power into heat. Brakes may also be described as mechanical devices for retarding the motion of the vehicle by means of friction. The engine converts the heat of combustion, resulting from the burning of fuel, into useful power which is used to propel the vehicle. The brakes convert the power of momentum (kinetic energy) of the moving vehicle into heat by means of friction.

Friction is the resistance to relative motion between two bodies in contact. Friction varies not only with different materials, but also with the condition of the materials. In general, friction is less between polished surfaces than between rough; it is less between surfaces of different material than between those of the same material; also it is less when one surface rolls over the other than when it slides. Friction is caused by the interlocking of the projections and depressions of the two surfaces in contact. Rolling friction is supposed to be caused by the fact that the wheel indents more or less the surface over which it rolls so that in effect it is always climbing a little hill. If the surface is very hard, the indentation is less so that the friction will be less.

The amount of friction is proportional to the pressure between the two surfaces in contact, and is independent of the area of the surface in contact.

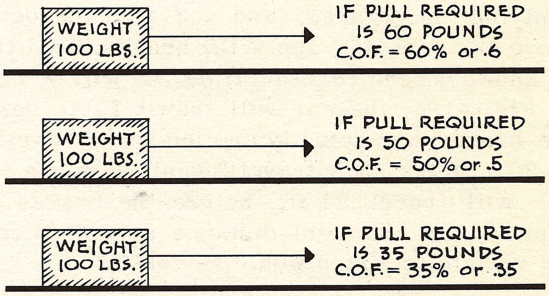
The amount of friction developed by any two bodies in contact is said to be their coefficient of friction. This is found by dividing the force required to slide the weight over the surface, by the weight of the object. For example, Fig. 41-2, if to slide the 100 lb. weight requires a 60 lb. pull, then the coefficient of friction would be 60 divided by 100, or .60. If only 35 lb. is required to slide the 100 lb. weight, then the coefficient of friction would be .35.

The coefficient of friction will change with any variation of the condition of the surfaces. Any lubricant will of course greatly reduce the coefficient of friction. That is why it is so important to keep any oil or grease from brake lining. Even an extremely damp day will cause some variation in the coefficient of friction.

BRAKING FORCES

Tremendous forces are involved when braking a vehicle. This arises from the fact that the vehicle must be brought to a stop in a much shorter time than is required to bring it up to speed. A simple method of explaining this is to make a comparison between the horsepower required to accelerate a vehicle, and the horsepower required to stop it.

A vehicle with a 100 h.p. engine requires about 60 seconds to accelerate to 60 m.p.h. However, the same vehicle is expected to be able to stop from 60 m.p.h. in not more than 6 seconds. In other words, the brakes must do the same amount of work as the engine but in one-tenth the time. This means they must develop approximately 1,000 h.p. to stop the vehicle.


WEIGHT 100 LBS.
IF PULL REQUIRED IS 60 POUNDS C.O.F. = 60% or .6
WEIGHT 100 LBS.
IF PULL REQUIRED IS 50 POUNDS C.O.F. = 50% or .5
WEIGHT 100 LBS.
IF PULL REQUIRED IS 35 POUNDS C.O.F. = 35% or .35

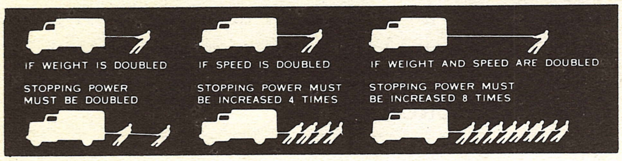
41-2. The coefficient of friction is equal to the force required to slide a body across a surface divided by the weight of the body.

EFFECT OF WEIGHT AND SPEED

The effect of weight and speed of the vehicle on braking is important for both passenger cars and trucks. If the weight of the vehicle is doubled, the energy of motion to be changed into heat energy is also doubled. In other words, if the weight is doubled, the amount of heat to be dissipated and absorbed is also doubled. For that reason it is important that vehicles not be overloaded.

The effect of higher speeds is much more serious. If the speed is doubled, four times as much stopping power must be developed, and the brakes must absorb or dissipate four times as much heat.

It naturally follows that if both weight and speed of a vehicle are doubled, the stopping power must be increased eight times and the brakes must absorb or dissipate eight times as much heat, Fig. 41-3.


IF WEIGHT IS DOUBLED
STOPPING POWER MUST BE DOUBLED
IF SPEED IS DOUBLED
STOPPING POWER MUST BE INCREASED 4 TIMES
IF WEIGHT AND SPEED ARE DOUBLED
STOPPING POWER MUST BE INCREASED 8 TIMES

41-3. Effect of weight and speed on braking.

STOPPING DISTANCE

As shown in Fig. 41-4, a vehicle which will just stop in 38 ft. from 20 m.p.h. will require 111 ft. to stop from 40 m.p.h. and 218 ft. from 60 m.p.h.

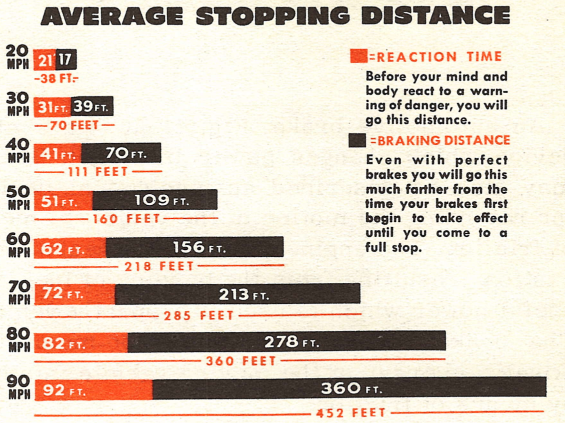
When calculating the distance required to stop a vehicle, it is necessary to consider the time required for the driver to note the need for applying the brakes, and the time needed to move his foot and apply the brakes. That time is known as the reaction time. As will be noted in Fig. 41-4, the car will travel 21 ft. before the brakes are actually applied when travelling at 20 m.p.h. When travelling at 90 m.p.h., the car will travel 92 ft., before the brakes are applied, and the total distance needed to bring the vehicle to a stop would be 452 ft.

BRAKE TEMPERATURES

As previously pointed out, brakes are devices which convert the energy of the moving vehicle into heat whenever the brakes are applied. This heat must be absorbed and dissipated by the brake parts. Unless the heat is carried away as fast as it is produced, the brake parts increase in temperature. The heat generated by brake applications is usually many times the rate of heat dissipation which results in high brake temperatures. These temperatures may become so high as to damage the brake lining, the brake drums, the brake fluid and in extreme cases the tires have been set on fire.

The factors that tend to increase brake temperatures include:

1. Load on vehicle.
2. Driver abuse.
3. Speed of vehicle.
4. Adjustment of brakes.
5. Care in installation of brake parts.
6. Balance of braking at each wheel.



41-4. Average stopping distances when travelling at various speeds.

The amount of heat developed in stopping a vehicle is easily calculated. Assuming a car weighing 4,000 lb. and travelling at a speed of 60 m.p.h. (or 88 ft. per second), the heat developed in stopping this car from that speed is found as follows:

Kinetic energy in ft. lb. $= \frac{W\ V^2}{64.4}$, in which W is the weight of the car in pounds and V the velocity in feet per second.

$$\text{Kinetic energy} = \frac{4000 \times 88^2}{64.4} = 480{,}994 \text{ ft. lb.}$$

Heat energy is measured in British thermal units (BTU's) and one BTU = 778 ft. lb. Therefore the heat energy of the car is:

$$\text{BTU} = \frac{480{,}994}{778} = 619 \text{ BTU}$$

If the car is stopped, the 619 BTU will go into the braking system. If we assume that all of this heat goes into the brake drums (usually about 90%) and also assuming that each brake drum weighs 10 lb. or a total of 40 lb. and the specific heat of the brake drum is .110 then the drum temperature rise would be

$$\frac{619}{40 \times .110} = 170^{\circ} \text{ F.}$$

and assuming that the atmospheric temperature was 80°, then the final drum temperature would be

$$80 + 170 = 250^{\circ} \text{ F.}$$

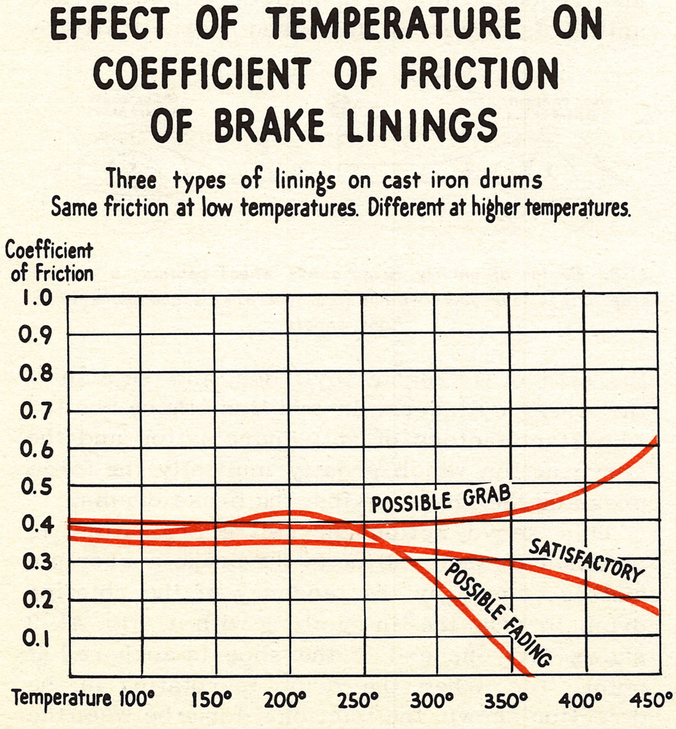
If several stops are made in rapid succession, so that the brakes will not have time to cool, much higher temperatures will be reached. Also if speeds are increased, or the weight of the vehicle is increased, temperatures will soar still higher. In fact, under extreme conditions of unbalanced brakes on a heavy truck having an emergency stop from high speed, enough heat will be generated to melt a cube of iron weighing 11.2 lb. It must be remembered that if the brake lining surface does not conform to the surface of the brake drum all the work of stopping will be done by a small area of brake lining. The same amount of work will be done, but being concentrated on a small area, the temperature will be a great deal higher. If the area of braking is one fourth the normal area, the temperature will be four times higher than it should be. If the full area of contact is 40 sq. in. and the normal braking temperature 150 deg., the temperature will then soar to 600 deg. if only one fourth of the braking area is used.

BRAKE AND TIRE FRICTION

When brakes are applied on a vehicle, the brake shoes are forced into contact with the brake drums, thereby slowing the rotation of the wheel. Then, the friction between the tires and the road surface slows the speed of the vehicle. However, the friction between the brake shoe and the brake drum does not remain constant, but tends to increase with the temperature. From tests the coefficient of friction of brake lining has been found to range from 0.35 to 0.50. Another variable is the materials of which the brake lining is made, and also the material of the brake drum. The friction of the tire on the road is approximately .02, but this also varies with the road surface.

The fastest stops are obtained with the wheels rotating. As soon as the wheels become locked, there is less friction and the car will not be stopped so quickly.

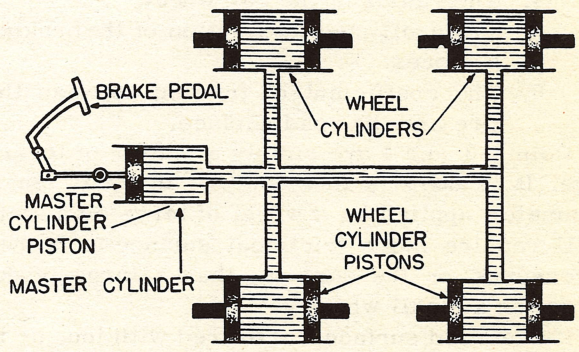
While the coefficient of friction of many linings tends to increase with higher temperatures, such is not always the case. This is brought out in Fig. 41-5, which shows how the coefficient of friction of one lining increased with higher temperatures, resulting in grabbing brakes. Another remained practically constant, while on a third lining, the coefficient dropped rapidly and fading brakes resulted.



41-5. Note how temperature effected the coefficient of friction of three different brake linings.

HYDRAULIC BRAKES

As was pointed out in the chapter on hydraulics, liquids are virtually incompressible, and pressure throughout a closed system will be the same. This principle is used to operate the service brakes on most passenger cars. A schematic drawing of a hydraulic brake system is shown in Fig. 41-6. In such a system, the foot pedal is attached to a master cylinder. As the pedal is depressed, it moves a piston within the master cylinder. The movement of this piston forces the hydraulic fluid throughout the system and into cylinders at each wheel. Here it causes the wheel cylinder pistons to



41-6. Schematic drawing of hydraulic brake system.

move, which in turn forces the brake shoes against the brake drums.

Fig. 41-7 shows how the force applied to the brake pedal is multiplied. In this instance, 800 lb. is applied to a piston area of 0.8 sq. in., resulting in a pressure in the system of 1,000 p.s.i. At the rear wheel cylinders which have an area of 0.7 sq. in., a force of 700 p.s.i. is produced for each piston making a total of 1400 p.s.i. The front wheel cylinders being larger, a combined force of 1,800 p.s.i. is produced.

WEIGHT TRANSFER

In Fig. 41-7, the wheel cylinders on the front wheels are larger than those on the rear wheels. The reason for this is to compensate for weight transfer to the front of the vehicle when the brakes are applied for a rapid stop. As a result of this weight transfer, the front brakes are required to do more work than the rear brakes.

This weight transfer effect comes about because the center of gravity of the automobile is located above the center of the car wheels as illustrated in Fig. 41-8. The result of this action is noticeable by a sinking of the front of the car, and simultaneous rising of the rear of the car whenever a severe brake application is made.

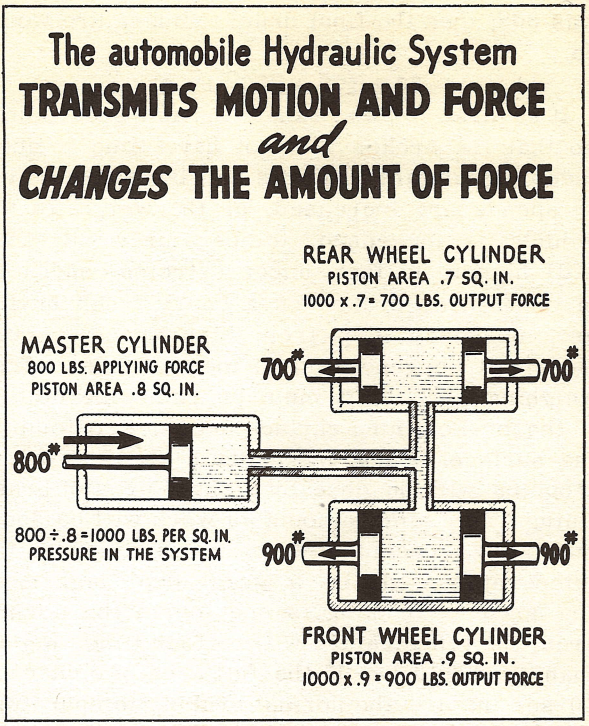
BRAKE EFFECTIVENESS

There are several factors that contribute to the effectiveness of brakes. These include:

1. The area of the brake lining.
2. The amount of pressure applied to the brake shoes.
3. The radius of the brake drum.
4. The radius of the car wheel.
5. The coefficient of friction of the braking surfaces.
6. The coefficient of friction between the tire and the road surface.

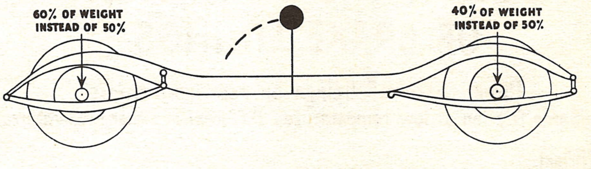
Points 3 and 4 are simply a matter of leverage. It is obvious that a brake drum of small diameter applied to a wheel of large diameter, will require more frictional surface or higher pressures on the surface, than a large brake drum on a small wheel.

If the road surface is covered with ice, or is in such condition that there is little friction between the tires and the road surface, braking effectiveness will be greatly reduced. Also, a worn tread on one tire and a new tread on another tire will provide unequal braking. As pointed out previously, maximum braking effort is obtained as long as the wheel is rotating. But once the brake has become locked and the wheel does not rotate, braking effectiveness is reduced.


The automobile Hydraulic System
TRANSMITS MOTION AND FORCE
and
CHANGES THE AMOUNT OF FORCE
REAR WHEEL CYLINDER
PISTON AREA .7 SQ. IN.
1000 x .7 = 700 LBS. OUTPUT FORCE
MASTER CYLINDER
800 LBS. APPLYING FORCE
PISTON AREA .8 SQ. IN.
700#
700#
800#
800 ÷ .8 = 1000 LBS. PER SQ. IN. PRESSURE IN THE SYSTEM
900#
900#
FRONT WHEEL CYLINDER
PISTON AREA .9 SQ. IN.
1000 x .9 = 900 LBS. OUTPUT FORCE

41-7. Showing how the force applied to the brake pedal is multiplied hydraulically.

Point 2 is among the more important points to be considered in the effectiveness of brakes. The pressure of the brake shoes against the brake drums starts with the force applied to the brake pedal. There it is multiplied by leverage and frequently further assisted by a power brake unit. This is further increased hydraulically, by the size of the master cylinder, and the size of the wheel cylinders. In addition, there are the important factors of self-energization and the servo action which greatly multipliy the force pressing the shoes against the brake drums.


60% OF WEIGHT INSTEAD OF 50%
40% OF WEIGHT INSTEAD OF 50%

41-8. Center of gravity being above wheel centers, a sudden stop will remove some weight from rear wheels and place it on front wheels.

This servo action and self-energization, is obtained by the location of the brake anchor pin and is caused by the tendency of the rotating drum to drag the lining along with it. Fig. 41-9 shows that one end of the shoe is anchored at point "B." When the drum is rotating in the direction shown, the frictional force between the brake drum and lining tries to turn the shoe around the anchor pin. Since the drum itself prevents this, the shoe is forced even more strongly against the drum than the applying force is pushing it. This is known as self-energization.

The nearer the center of rotation the anchor pin is located, the more powerful will be the wedging action. This wedging action starts at the toe of the shoe, and keeps increasing as it nears the anchor pin, Fig. 41-10. If the drum is revolved in the opposite direction, there will be no self-energization. However, as there are two shoes, one or the other is effective either way the drum turns.

This self-energization can be amplified to include both shoes by letting one shoe push the other shoe, Fig. 41-11. When such is the case, the amplification of forces is known as servo-action. To accomplish this, the shoes are linked together at the bottom and clearance is provided between the ends of the shoes and the anchor pin, so the shoes can be rotated slightly in relation to the axle shaft or wheel spindle. Then, as the brakes are applied, both the shoes will move with the rotation of the drum, until the rearward shoe is stopped by the anchor pin and the forward shoe is also stopped, as it is linked to the rearward shoe through the connecting link or adjusting screw.

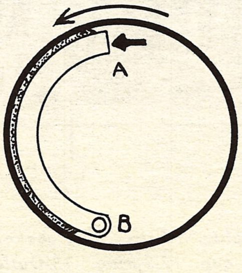
The shoe that starts or generates the servo-action is known as the primary shoe, and the other shoe is the secondary.

BRAKE LINING MATERIALS

There are two main types of brake linings:

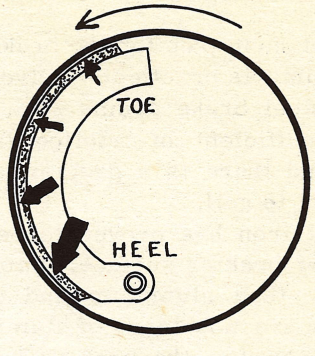
1. Organic
2. Metallic

Organic lining consists basically of a gray-white compound of asbestos, filler materials and powdered resins which are thoroughly mixed, formed into shape and placed under heat and pressure until a hard slate-like board is formed. The material is cut and bent into individual segments and attached to brake shoes. This is known as molded lining. Some organic lining is woven from strands of asbestos and threads of other materials and impregnated with a rubber compound. In some instances, organic brake lining will also have fine metal wires included.

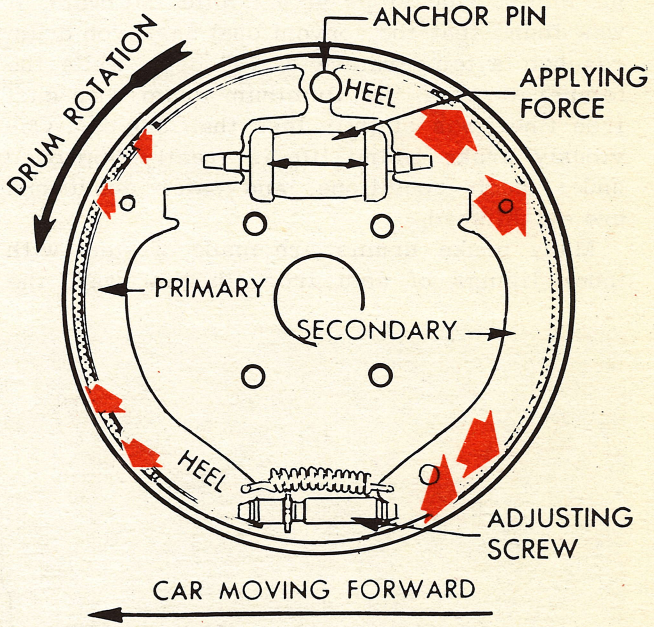


41-9. The shoe is pivoted at (B) and the force applied at (A).

Metallic brake lining is made of sintered metal, and is composed of finely powdered iron or copper, graphite and lesser amounts of inorganic fillers and friction modifiers. After thorough mixing, a lubricating oil is added to prevent segregation of the different materials. The mixture is then put through a briquetting process and compressed into the desired form.



41-10. The relative size of the arrows indicates the increase of pressure from the toe to the heel with the pivot set toward the center.



41-11. Showing how thrust of brake shoes against brake drum is multiplied by servo-action.

The organic type brake lining is used almost exclusively for ordinary brake service. Under extreme braking conditions as encountered in service such as police cars, ambulance and sports car service, the metallic type lining is being used extensively. Under such extreme service, the frictional characteristics of the metallic lining are more constant than that of the organic lining. However, metallic brake lining has low initial friction and resultant hard pedal.

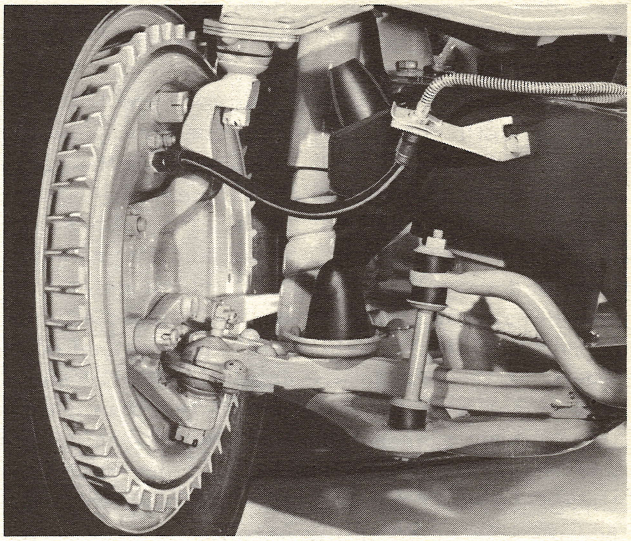
BRAKE DRUM MATERIALS

The use of cast iron for the braking surface of brake drums is practically universal. In the past some steel brake drums were used, however, the coefficient of friction is less than cast iron, and there is a greater tendency for such material to gall.

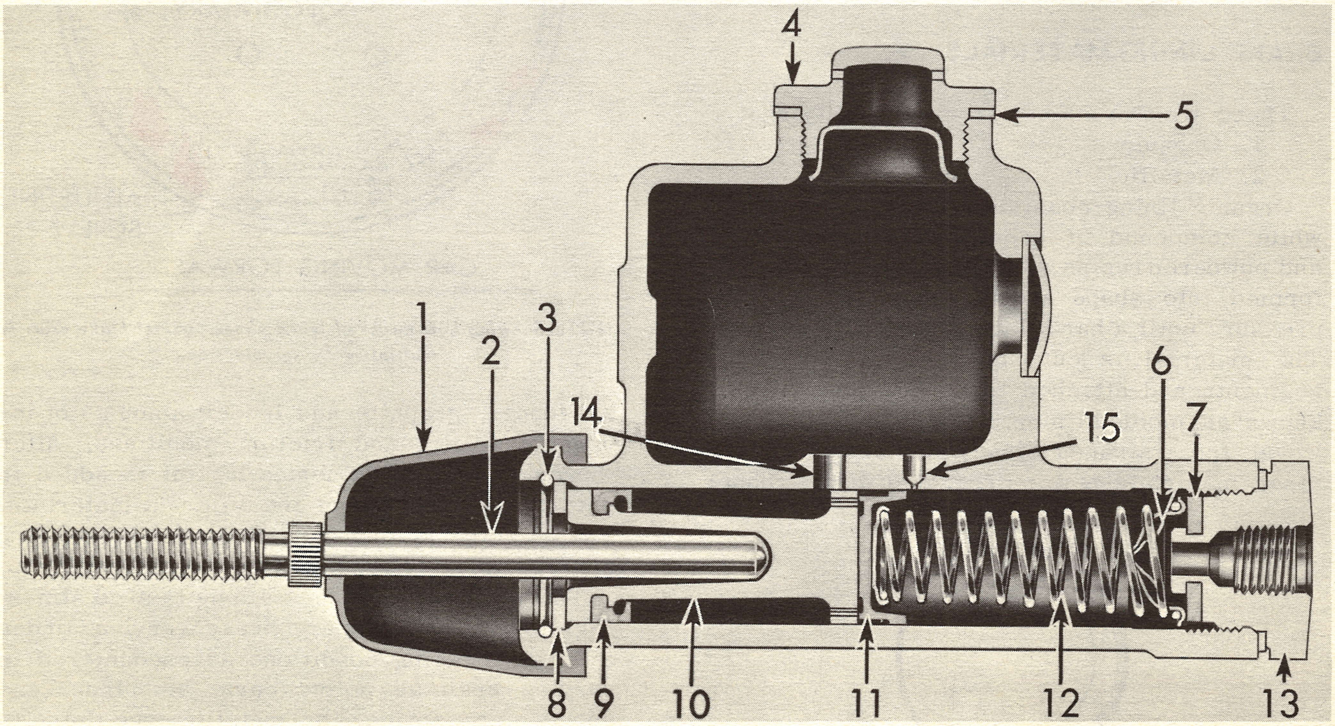
While cast iron has proved to be ideal material for the braking surface, it conducts heat more slowly than aluminum and as a result some drums are now made of aluminum with a cast iron liner for the braking surface. Because of its higher conductivity of heat a brake drum of such construction will operate at much lower temperatures. In some tests made with 50 m.p.h. fade stops at 0.2 mile intervals, it was found that the conventional cast iron drum reached a temperature of 700 deg., while the temperature of the aluminum drum with cast iron liner was slightly less than 500 deg. Obviously brake lining life is greatly improved under such conditions, and safer conditions are established.

Many brake drums are made of steel with inner linings of cast iron. In this way, the assembly has the strength of the steel, and the frictional properties of cast iron. In addition, there is no difficulty in getting the cast iron to bind with the steel, which is the case when aluminum is used.

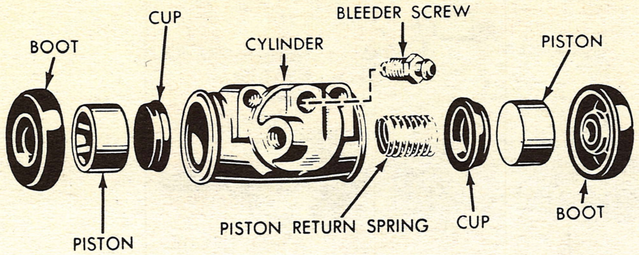
To aid in the dissipation of heat, brake drums, regardless of the material of which they are made, are usually provided with some form of cooling fin, Fig. 41-12.



41-12. Note cooling fins on this brake drum. Other drums will have circumferential cooling fins.



41-13. Typical master cylinder. 1-Rubber boot. 2-Push rod. 3-Lock ring. 4-Filler plug. 5-Filler plug gasket. 6-Valve assembly. 7-Valve seat. 8-Flat washer. 9-Secondary cup. 10-Piston. 11-Primary cup. 12-Spring. 13-Outlet fitting. 14-Breather port. 15-Compensating port.



41-14. Exploded view of typical wheel cylinder.

OPERATION OF HYDRAULIC BRAKES

The conventional hydraulic brake system is pedal operated, and applies the brakes at all four wheels with equalized pressure.

A hydraulic system consists of one master cylinder, Fig. 41-13, connected by pipes and flexible tubing, Fig. 41-1, to a wheel cylinder, Fig. 41-14, or wheel cylinders, Fig. 41-15, which control the movement of the brake shoes at each wheel.

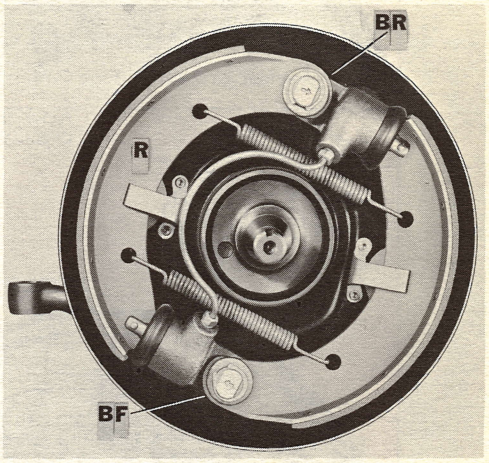
The master cylinder, connecting lines and wheel cylinders, are filled with special hydraulic fluid which is forced through the system by the movement of the master cylinder piston.

When the brakes are fully released, the master cylinder piston, Fig. 41-13 and Fig. 41-16, view A, is held against the stop plate, and the primary cup is held just clear of the compensating port by the master cylinder spring, which also holds the check valve against its seat on the head nut. The pressure chamber is filled with fluid at atmospheric pressure due to the open compensating port and reservoir vent. All lines and cylinders are filled with fluid under a static pressure of 8 - 16 lb., which helps to hold the lips of the wheel cylinder cups in firm contact with the cylinder walls to prevent loss of fluid or the entrance of air into the system.

When the brake pedal is applied, the push rod forces the master cylinder piston and primary cup forward, Fig. 41-16, view B. As this movement starts, the lip of the primary cup covers the compensating port to prevent escape of the fluid back to the reservoir. Continued movement of the piston builds pressure in the pressure chamber, and fluid is then forced through holes in the check valve and out into the lines leading to each of the wheel cylinders. Fluid forced into the wheel cylinders between the pistons and cups, Fig. 41-16, view B, causes pistons and connecting links to move outward, forcing the brake shoes into contact with the brake drums.

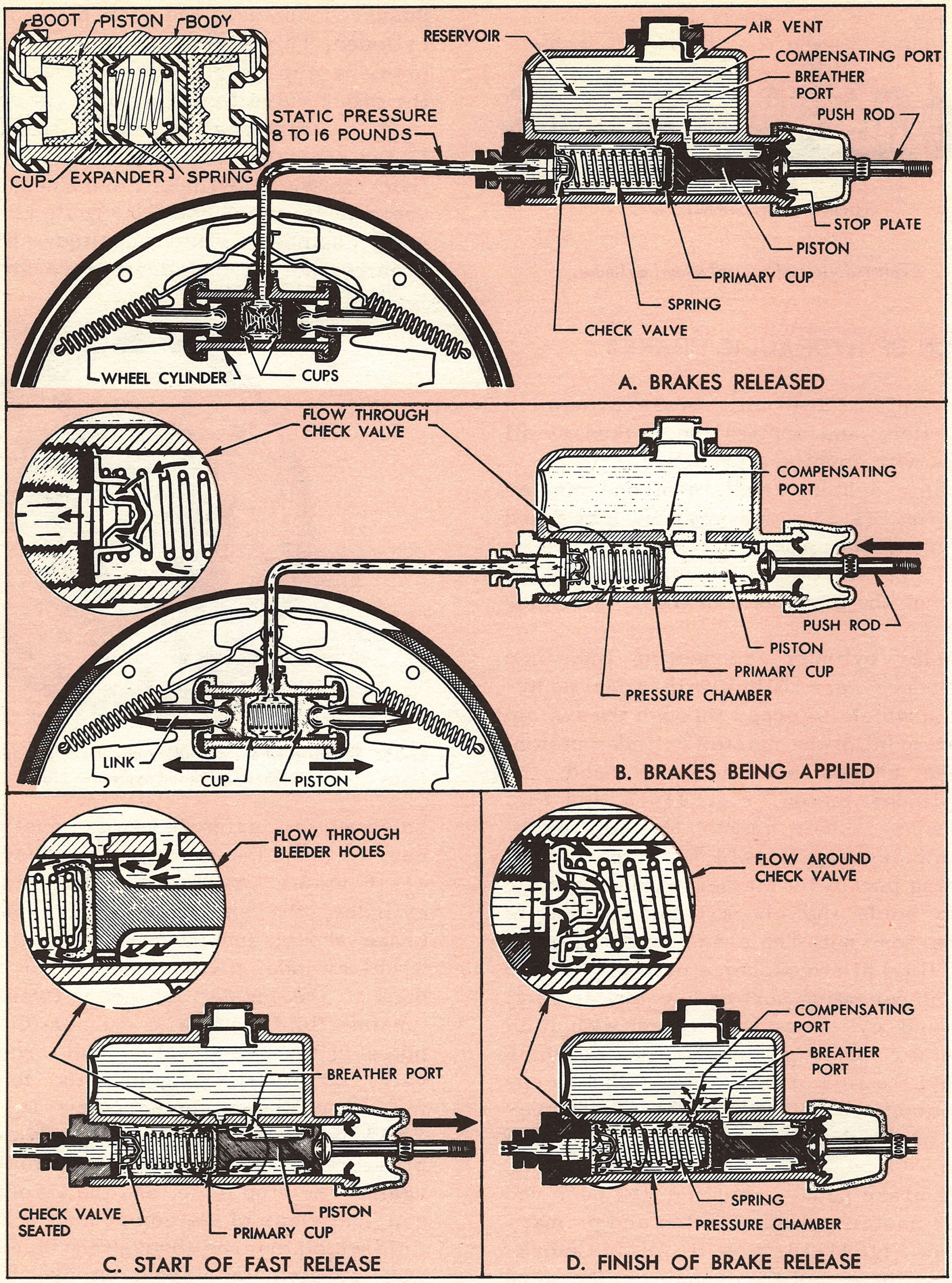
When the brake pedal is released, the master cylinder spring forces the pedal back until the push rod contacts the stop plate in the master cylinder. This spring also forces the piston and primary cup to follow the push rod, and pushes the check valve firmly against its seat.

At the start of a fast release, the piston moves faster than the fluid can follow it in returning from the wheel cylinders and lines, and a partial vacuum is momentarily created in the pressure chamber. Fluid supplied through the breather port is then drawn through the bleeder holes in the piston head, and past the primary cup, to keep the pressure chamber filled, Fig. 41-16 view C. As pressure drops in the master cylinder, the shoe return springs retract all brake shoes, and the connecting links push the wheel cylinder pistons inward, forcing the fluid back to the master cylinder. Pressure of returning fluid causes a rubber disk to close holes in the check valve, and forces the check valve off its seat against the tension of the master cylinder spring, view D, Fig. 41-16. Fluid then flows around the check valve into the pressure chamber. With the piston bearing against the stop plate, and the lip of the primary cup just clear of the compensating port, excess fluid which entered through the bleeder holes, or was created by expansion due to increased temperature, now returns to reservoir through uncovered compensating port. When pressure in wheel cylinders and lines becomes slightly less than the tension of master cylinder spring, the check valve returns to its seat on head nut to hold the 8 to 16 lb. static pressure in the lines and cylinders.



41-15. Separate wheel cylinders are used for each brake shoe of this Lockheed hydraulic brake.

Split-System Master cylinder: The split-system cylinder, also known as the dual master cylinder, Fig. 41-16a, is so designed that the front and rear brakes have separate hydraulic systems. Should a leak occur in the front system, the


BOOT
PISTON
BODY
STATIC PRESSURE 8 TO 16 POUNDS
CUP
EXPANDER
SPRING
RESERVOIR
AIR VENT
COMPENSATING PORT
BREATHER PORT
PUSH ROD
STOP PLATE
PISTON
PRIMARY CUP
SPRING
CHECK VALVE
WHEEL CYLINDER
CUPS
A. BRAKES RELEASED
FLOW THROUGH CHECK VALVE
COMPENSATING PORT
PUSH ROD
PISTON
PRIMARY CUP
PRESSURE CHAMBER
LINK
CUP
PISTON
B. BRAKES BEING APPLIED
FLOW THROUGH BLEEDER HOLES
BREATHER PORT
CHECK VALVE SEATED
PISTON
PRIMARY CUP
C. START OF FAST RELEASE
FLOW AROUND CHECK VALVE
COMPENSATING PORT
BREATHER PORT
SPRING
PRESSURE CHAMBER
D. FINISH OF BRAKE RELEASE

41-16. Operation of typical hydraulic brake system.

rear system would still be in operation making it possible to stop the car. Similarly, if a leak occurs in the rear system, the front brakes would not be affected.

As shown in Fig. 41-16a and 41-16b, the split-system master cylinder is provided with a secondary piston and a primary piston, one supplies hydraulic pressure to the front brake system, while the other supplies pressure to the rear hydraulic brake system.

HYDRAULIC BRAKE FLUID

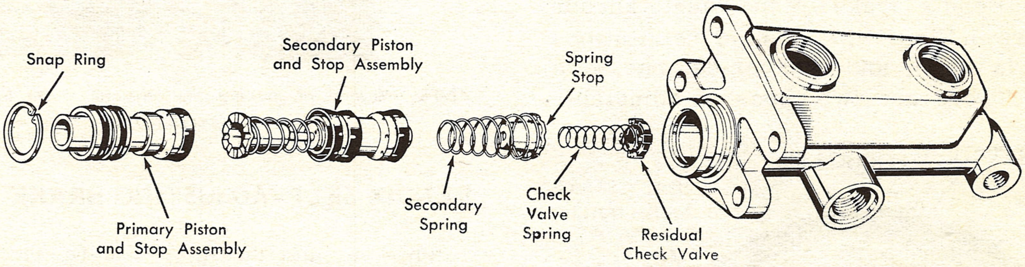
To provide positive brake action under all conditions, brake fluid must meet a lot of requirements. First of all, hydraulic brake fluid must not swell or soften the rubber parts used throughout the system. Failure to meet that requirement results in brakes locking up, leaks or short life of rubber parts. It must also be compatible with the different metals used in the hydraulic system. If any rusting or corrosion is caused, the result will be frozen brakes, pulling brakes or loss of brakes due to leaks.

Hydraulic brake fluid must not vaporize at the highest temperature encountered in actual service. Failure to meet that requirement, results in complete loss of brakes without warning. It must remain fluid at low temperatures, and must remain in a fluid state even when a small amount of water is added. Hydraulic fluid must also act as a lubricant to the moving parts of the system. It must retain all its characteristics over a long period of time. It must also mix satisfactorily with other makes of hydraulic brake fluid.

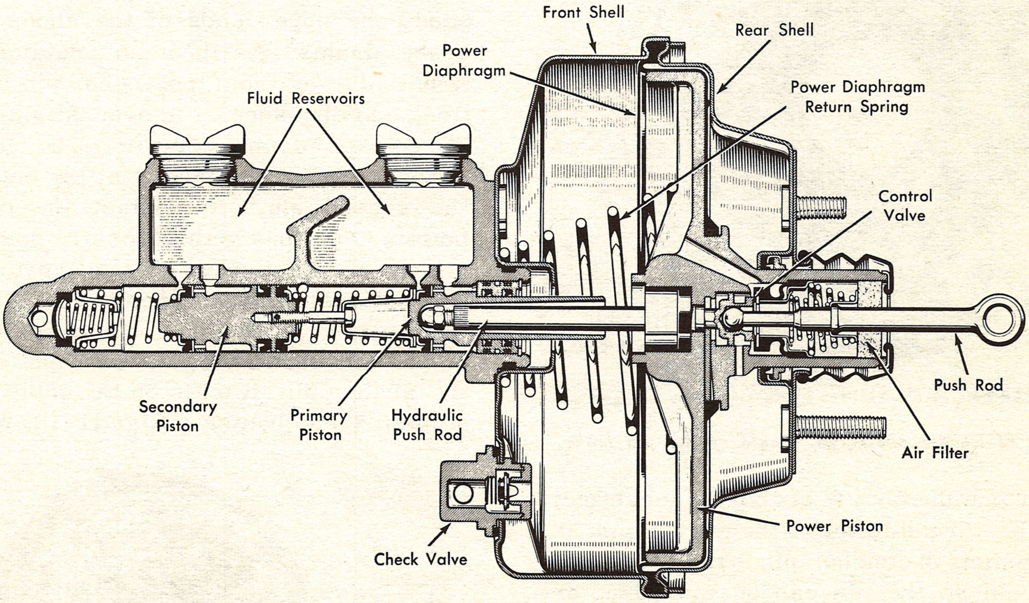
As previously pointed out, stopping a 4,000 lb. car from 60 m.p.h. will result in raising the temperature of the brakes to 250 deg., and 700 deg. will be reached if repeated stops are made every 0.2 miles from 50 m.p.h. With such temperatures, it is easily understood that care must be exercised in selecting brake fluid. Only hydraulic fluid meeting the Society of Automotive Engineers specification 70 R 1, or better, should be used.

When the brake fluid in the system becomes hot enough to vaporize (SAE specification is 295 deg.) gas pockets or bubbles are formed in the tops of the cylinders. When the fluid starts to vaporize, it emits gas and a drop of fluid changed into vapor forms a gas bubble many times the volume of the liquid drop. This gas formation forces some of the brake fluid back through the lines, through the master cylinder check valve, and through the small by-pass hole into the reservoir.

The check valve holds a static pressure in the line which tends to keep the fluid from boiling. Once the brake fluid reaches the boiling point, it may continue to change into gas until a large bubble is formed. If this bubble has pushed more brake fluid back into the reservoir than one stroke of the pedal can pump back into the system, complete loss of brakes will occur. Such gas is easily compressible, and small quantities produce what is known as


Snap Ring
Secondary Piston and Stop Assembly
Spring Stop
Primary Piston and Stop Assembly
Secondary Spring
Check Valve Spring
Residual Check Valve

41-16a. Sectional view of Bendix type split-system master cylinder.


Front Shell
Rear Shell
Power Diaphragm
Power Diaphragm Return Spring
Fluid Reservoirs
Control Valve
Push Rod
Secondary Piston
Primary Piston
Hydraulic Push Rod
Air Filter
Power Piston
Check Valve

41-16b. Details of Bendix split-system master cylinder.

a "spongy pedal" with partial loss of braking.

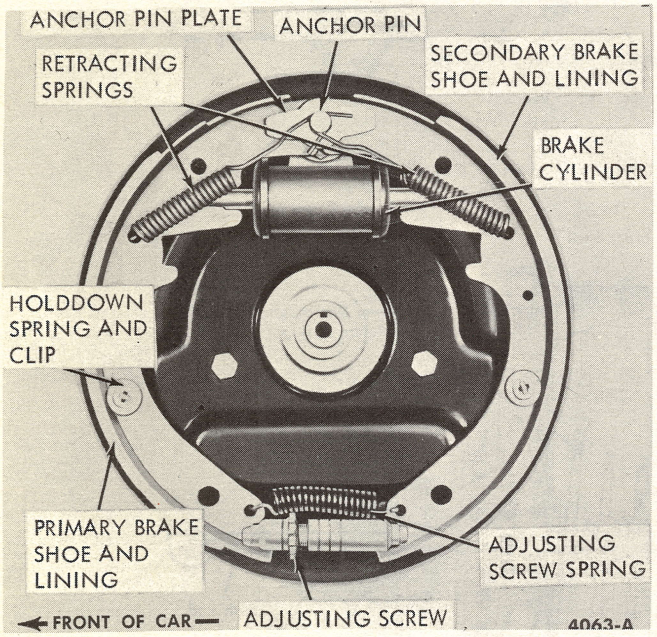
In addition to vapor lock occurring in the wheel cylinders, it may also occur in the master cylinder. In such cases brakes will fail without warning. Pumping the pedal will not remove the vapor lock.

Mountain driving puts increased duty on brakes and brake fluid. With every 2,000 ft. increase in altitude, the atmospheric pressure drops approximately one pound and the boiling point of the brake fluid drops 2 deg. to 3 deg. This naturally increases the tendency toward vapor lock.

BRAKE TYPES

BENDIX SINGLE ANCHOR

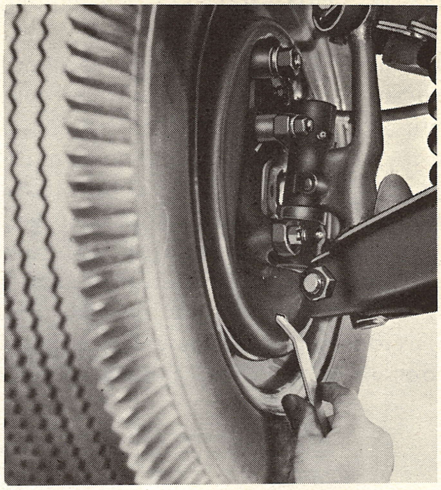
A typical Bendix brake of the single anchor type is shown in Fig. 41-17. In some installations the anchor is fixed, and in other designs, it is adjustable. There are two types of adjustable anchors. In one design the anchor is eccentric, which can be turned to move the anchor pin. In the other design, the anchor pin is mounted in an elongated hole so the pin can be moved up or down, as desired.


ANCHOR PIN PLATE
ANCHOR PIN
RETRACTING SPRINGS
SECONDARY BRAKE SHOE AND LINING
BRAKE CYLINDER
HOLDDOWN SPRING AND CLIP
PRIMARY BRAKE SHOE AND LINING
ADJUSTING SCREW SPRING
← FRONT OF CAR —
ADJUSTING SCREW
4063-A

41-17. Details of Bendix duo-servo, single anchor pin brake.

Only a single wheel cylinder is used in this Bendix brake, and the shoes are held in the released position by means of individual springs from the anchor pin to each shoe. Each shoe is also provided with a hold down spring and clip to keep the shoes snugly against the backing plate.

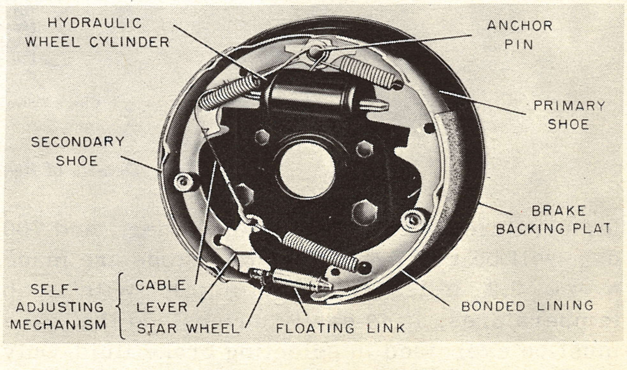
A single adjustment is provided, which is reached through a port in the backing plate, Fig. 41-18. Raising the handle of the tool upward will expand the shoes against the brake drums.



41-18. Method of making the adjustment on the Bendix duo-servo brake.

BENDIX SELF-ADJUSTING BRAKE

This brake, which closely resembles the Bendix single anchor brake, is illustrated in Fig. 41-19. The two brake shoes rest on the single anchor pin, until the wheel cylinder expands the upper ends of the shoes against the brake drums. As the drum rotates, one shoe is pulled away from the anchor pin by this rotation, and the shoe is moved slightly in the direction of drum rotation. The floating link connecting the two shoes at the bottom, forces the second shoe to contact the drum at the bottom, and thus both shoes are energized. The action of the brake is similar to that of the conventional single anchor brake. When applying the brakes in reverse, the opposite shoe becomes the lead shoe, and as it pulls away from the anchor pin, it pulls on the cable of the self-adjusting mechanism, Fig. 41-19, which raises

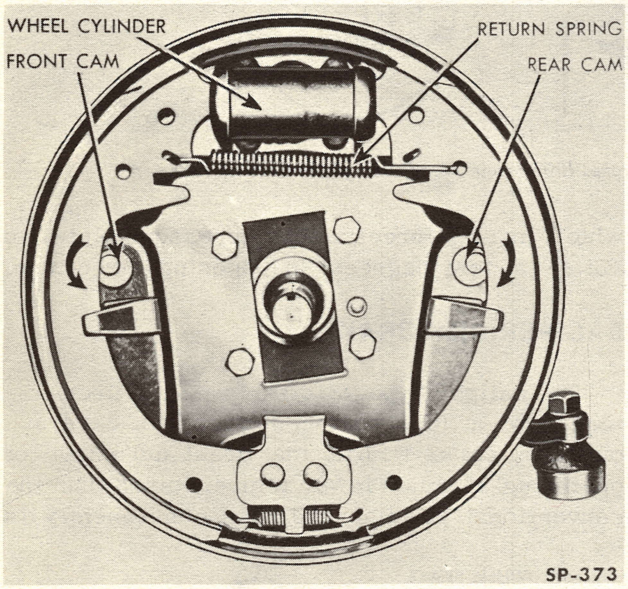

HYDRAULIC WHEEL CYLINDER
ANCHOR PIN
PRIMARY SHOE
SECONDARY SHOE
BRAKE BACKING PLAT
SELF-ADJUSTING MECHANISM
CABLE
LEVER
STAR WHEEL
FLOATING LINK
BONDED LINING

41-19. Bendix self adjusting brake.

the adjusting lever. When sufficient lining wear has occurred and not before, the lever can engage the next notch in the star adjusting wheel. A spring on the lever pulls it down and this increases the length of the floating link 0.0005 in. to expand the shoes. This self adjusting feature operates only when the car is moving backward and the brakes are applied.

BENDIX HYDRAULIC

In this type brake, Fig. 41-20, the ends of the brake shoes bear directly on the pistons in the wheel cylinder. Only a single shoe retracting spring is used, but separate adjustments are provided for the shoes. These shoes are of the eccentric or cam type.



41-20. Bendix hydraulic brake as used on Rambler, Nash and others. Note shoe adjusting cams.

HUCK - CHEVROLET BRAKE

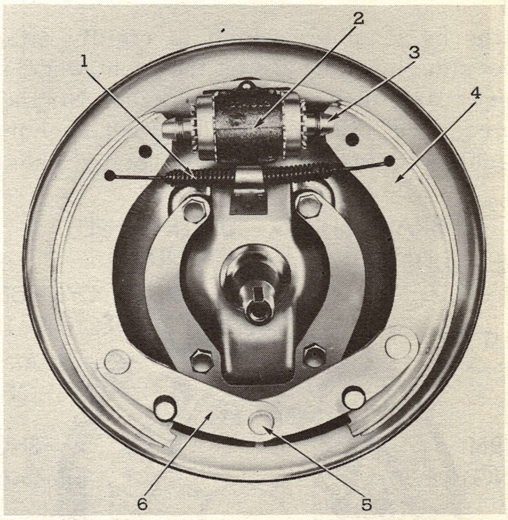
The unusual feature of this brake is the articulated link which connects the lower ends of the shoes together. The pivot pin for the articulated link, Fig. 41-21, is anchored to the brake backing plate. There is a double lever action on the shoes, which provides self energization. Each shoe has its own adjustment.

LOCKHEED HYDRAULIC

The front brakes of a Lockheed hydraulic brake system provide individual wheel cylinders for each brake shoe, Fig. 41-15, while the rear brakes use a single wheel cylinder for the operation of both shoes, Fig. 41-22. In the case of the front brakes, two adjustments are provided for each shoe, a cam shoe stop, and an eccentric anchor. Similarly, the rear brake shoes also have two adjustments. The illustration shows a brake gauge which is used when making adjustment.

CHRYSLER CENTER-PLANE BRAKE

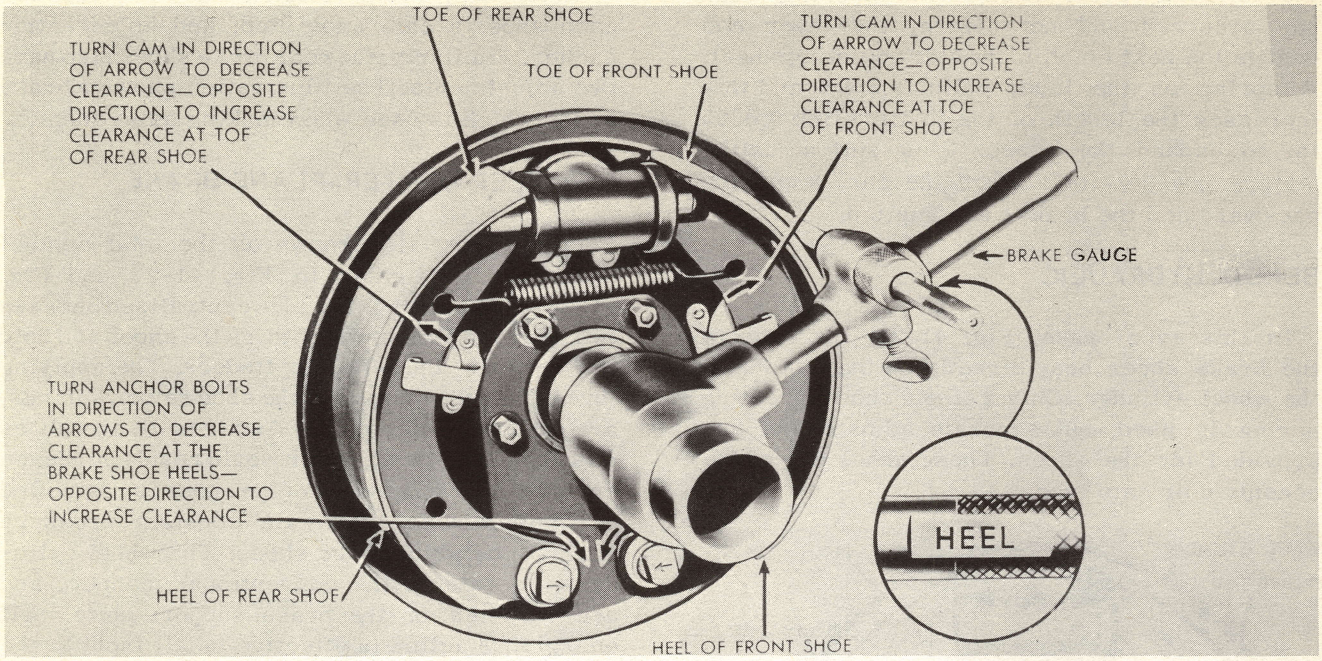
This brake, also known as the total contact brake, is illustrated in Fig. 41-23 and Fig. 41-24. The braking action is centralized between two support plates, which align the shoes and hold the anchors and wheel cylinders. The applying force from the piston and the shoe return springs, are all in a center plane. As a result, the shoes do not tend to twist, which would result in uneven contact. Side movement of the shoes is controlled by guides which maintain constant pressure against the webs of the shoes. The wheel cylinders operate in the conventional manner, and are mounted on the brake support plate. Self energizing action is effective on all front brake shoes, and the rear brake front shoe when the car is moving forward, and self energizing action on the rear shoe of the rear brakes when the car is backing.



41-21. Huck type brake. 1-Retracting spring. 2-Wheel cylinder. 3-Adjusting screw. 4-Brake shoe. 5-Anchor pin. 6-Articulating link.

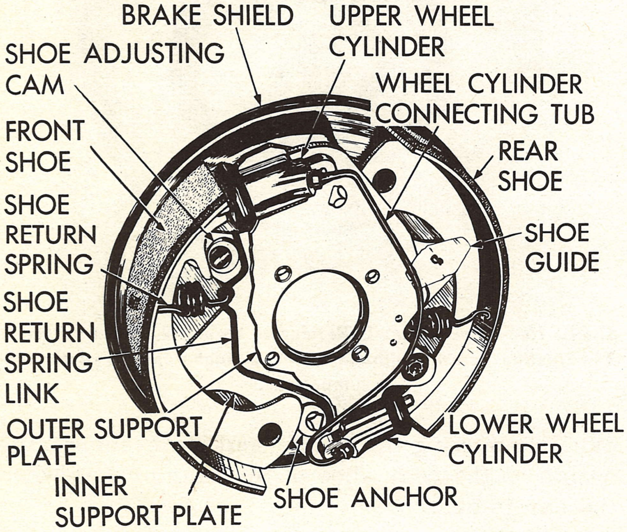
CHRYSLER DISK BRAKES

Instead of having brake shoes expanding outward against the interior of the brake drum, the Chrysler disk brake presses disks against the sides of rotating housing to provide deceleration. The construction is illustrated in Fig. 41-25 and Fig. 41-26. Two pressure plates with segmented lining are provided, and are held in


TOE OF REAR SHOE
TURN CAM IN DIRECTION OF ARROW TO DECREASE CLEARANCE—OPPOSITE DIRECTION TO INCREASE CLEARANCE AT TOE OF REAR SHOE
TOE OF FRONT SHOE
TURN CAM IN DIRECTION OF ARROW TO DECREASE CLEARANCE—OPPOSITE DIRECTION TO INCREASE CLEARANCE AT TOE OF FRONT SHOE
BRAKE GAUGE
TURN ANCHOR BOLTS IN DIRECTION OF ARROWS TO DECREASE CLEARANCE AT THE BRAKE SHOE HEELS—OPPOSITE DIRECTION TO INCREASE CLEARANCE
HEEL
HEEL OF REAR SHOE
HEEL OF FRONT SHOE

41-22. Rear shoe construction of Lockheed hydraulic brake. Note gauge for adjusting clearance of shoes.

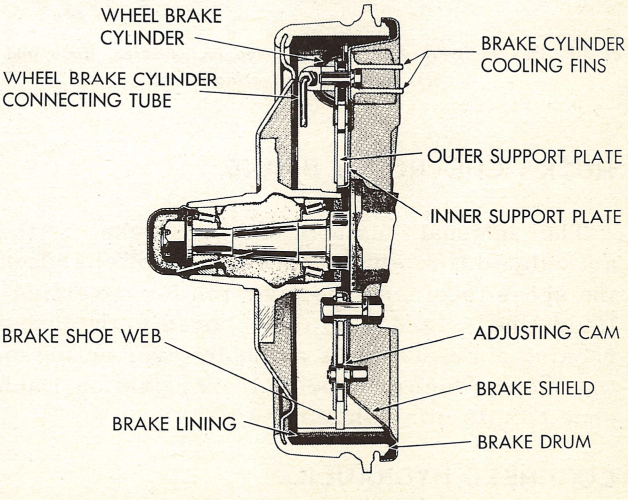
position by a spider which is rigidly attached to the steering knuckle on the front wheels and the rear axle housing at the rear. Notches in the pressure plates coincide with anchors on the spider to prevent rotation of the pressure plates. Braking occurs when the two plates are pushed apart until they are in contact with the inside faces of the rotating housing. A series of steel balls located between the two pressure plates, forces the plates apart when the brakes are applied. This action results from the balls being forced up ramps on the pressure plates, which in turn forces the two pressure plates to rotate a few degrees in opposing directions.


BRAKE SHIELD
UPPER WHEEL CYLINDER
SHOE ADJUSTING CAM
WHEEL CYLINDER CONNECTING TUB
FRONT SHOE
REAR SHOE
SHOE RETURN SPRING
SHOE GUIDE
SHOE RETURN SPRING LINK
OUTER SUPPORT PLATE
LOWER WHEEL CYLINDER
INNER SUPPORT PLATE
SHOE ANCHOR

41-23. Construction of center plane brake.

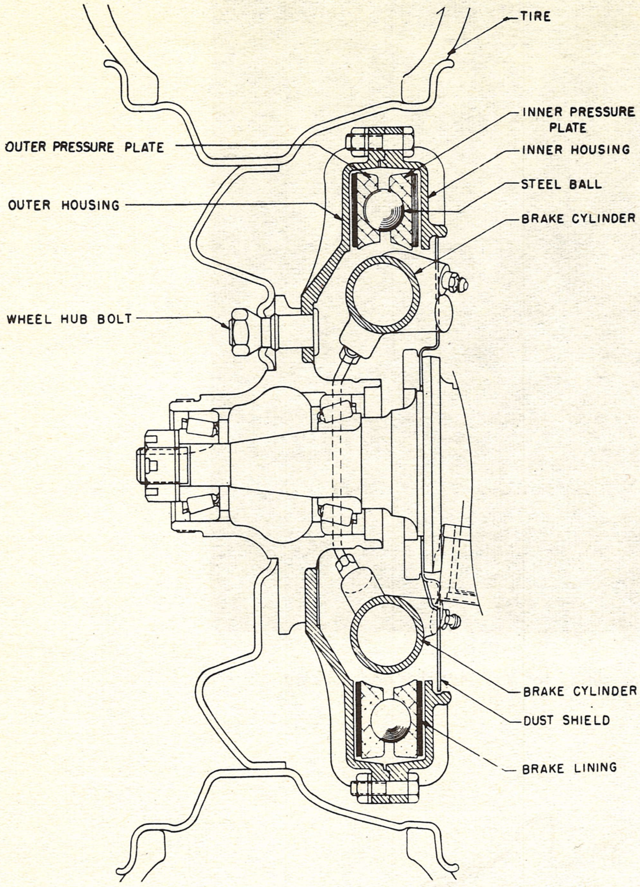
CALIPER DISK BRAKE

The caliper type of disk brake is used extensively on higher priced European cars and on race cars. It has the great advantage of operating at much lower temperatures than the conventional drum brake, and consequently is less liable to fading conditions.

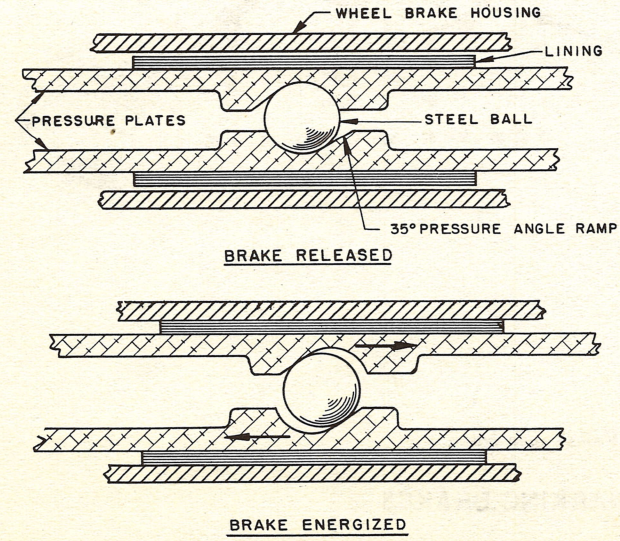

WHEEL BRAKE CYLINDER
BRAKE CYLINDER COOLING FINS
WHEEL BRAKE CYLINDER CONNECTING TUBE
OUTER SUPPORT PLATE
INNER SUPPORT PLATE
BRAKE SHOE WEB
ADJUSTING CAM
BRAKE SHIELD
BRAKE LINING
BRAKE DRUM

41-24. End view of center plane brake.

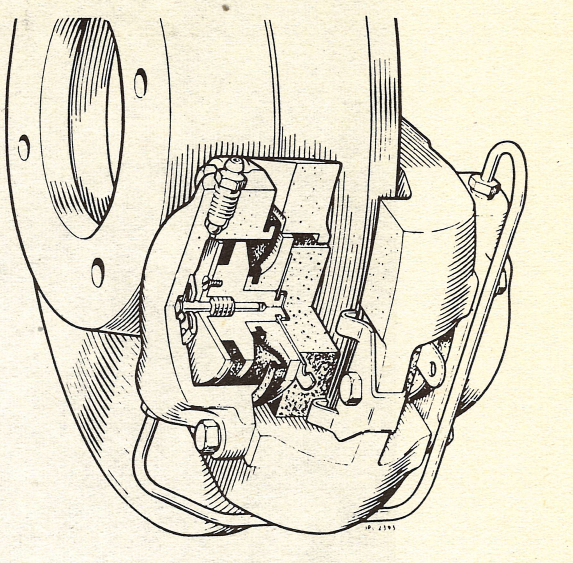
The Dunlop disk brake, such as is used on the British Jaguar and other European cars is shown in Fig. 41-27. In this design, each wheel brake comprises a hub-mounted disk rotating with the wheel, and a braking unit or caliper rigidly attached to the suspension member. The caliper straddles the disk, and includes the friction pad assemblies. Each friction pad is located in a parallel slot extending radially through the caliper, so the pads can be quickly removed and replaced, without dismantling the entire unit. The pads are held in position by a clip fastened by a single nut and bolt; or if to be used on a race car, by a quick release pin. As shown in Fig. 41-27, the pad retractor mechanism is enclosed within the cylinder and piston assembly. On brake release, the piston is withdrawn by the retractor a preset amount into the cylinder, so the pad to which it is clipped, is brought correspondingly clear of the disk.


TIRE
INNER PRESSURE PLATE
OUTER PRESSURE PLATE
INNER HOUSING
STEEL BALL
OUTER HOUSING
BRAKE CYLINDER
WHEEL HUB BOLT
BRAKE CYLINDER
DUST SHIELD
BRAKE LINING

41-25. This cross-section shows the construction of the Chrysler disc brake as mounted on the wheel.

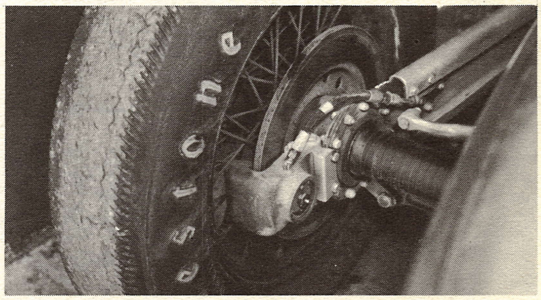

WHEEL BRAKE HOUSING
LINING
PRESSURE PLATES
STEEL BALL
35° PRESSURE ANGLE RAMP
BRAKE RELEASED
BRAKE ENERGIZED

41-26. The brake linings are pushed apart and against the drum by steel balls rolling in a ramp as shown.



41-27. Dunlop disk brake as used on the British Jaguar and other European cars.

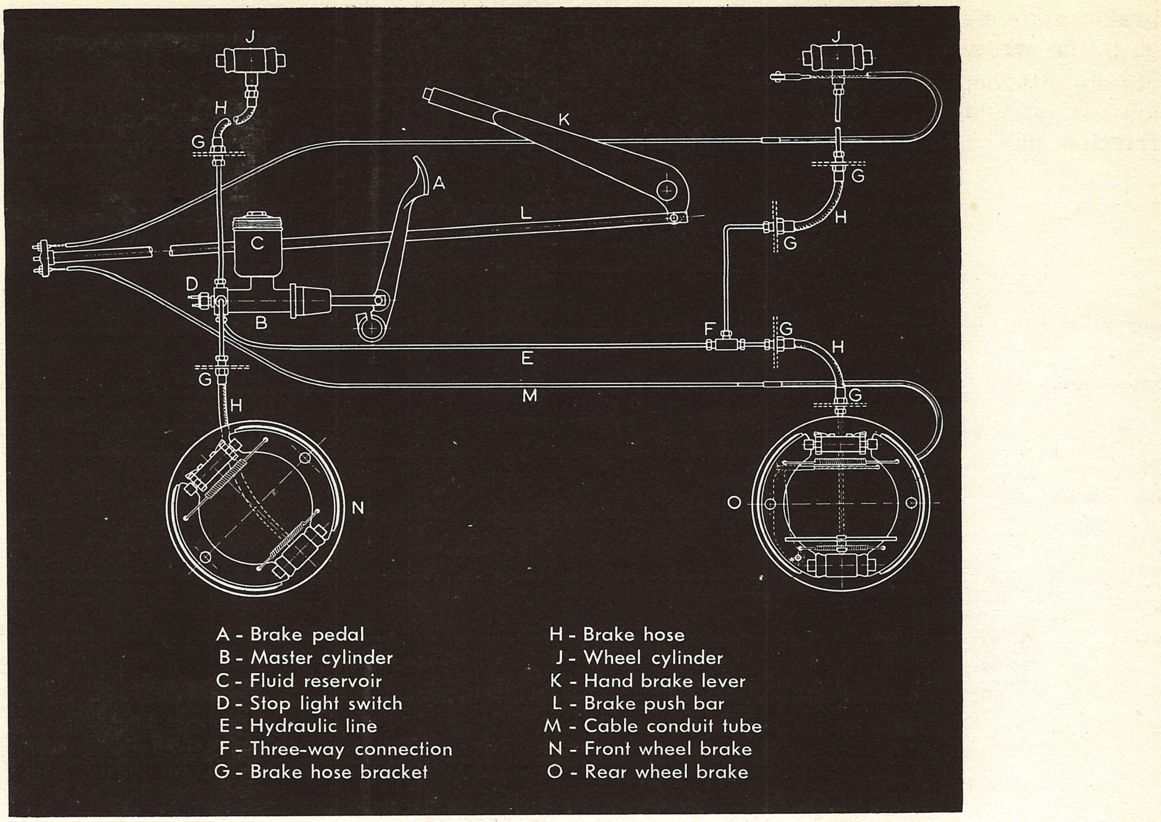
The caliper type brake as used on many American race cars is shown in Fig. 41-28. In operation, this brake closely follows the Dunlop design.



41-28. Caliper or spot brake as used on many American race cars.

VOLKSWAGEN BRAKES

The hydraulic brake used on the German Volkswagen is shown in Fig. 41-29. The entire hydraulic system is shown in exploded form in Fig. 41-30. The details of the actual brake are


J
J
K
H
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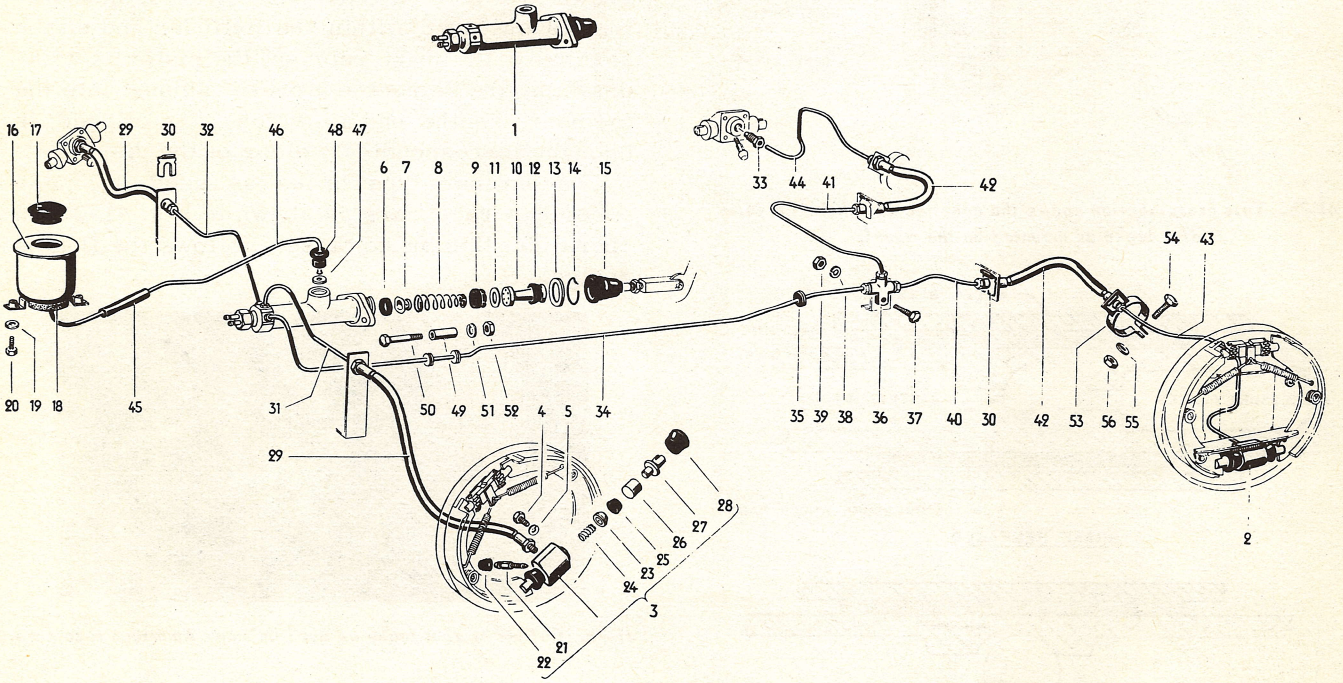
A
G
L
H
C
G
D
B
F
G
H
E
G
M
G
H
N
O

A - Brake pedal
B - Master cylinder
C - Fluid reservoir
D - Stop light switch
E - Hydraulic line
F - Three-way connection
G - Brake hose bracket
H - Brake hose
J - Wheel cylinder
K - Hand brake lever
L - Brake push bar
M - Cable conduit tube
N - Front wheel brake
O - Rear wheel brake

41-29. The Volkswagen brake uses the same rear shoes for both service and parking.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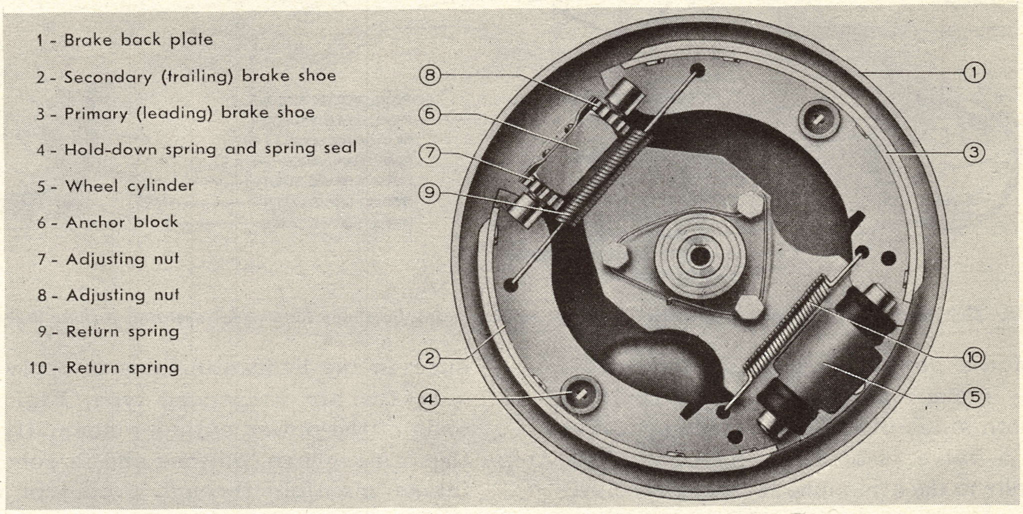
41-30. Exploded view of the Volkswagen brake.

shown in Fig. 41-31. As indicated in Fig. 41-31, each shoe has a separate adjustment. The hand brake operates the same rear shoes as are used for the service brake.

PARKING BRAKES

When the parking brake is mounted on the drive shaft, it is usually operated by a cable within a conduit leading to a hand lever. Multiplication of the leverage at the brake band cam or lever is obtained by a considerable leverage at the brake hand lever or parking brake pedal lever, Fig. 41-32.

An external type of parking brake is shown in Fig. 41-32, and an internal expanding type brake is shown in Fig. 41-33. On the external band type construction, the band is anchored at the center, and the two ends of the band are tightened around the drum by means of levers.


1 - Brake back plate
2 - Secondary (trailing) brake shoe
3 - Primary (leading) brake shoe
4 - Hold-down spring and spring seal
5 - Wheel cylinder
6 - Anchor block
7 - Adjusting nut
8 - Adjusting nut
9 - Return spring
10 - Return spring
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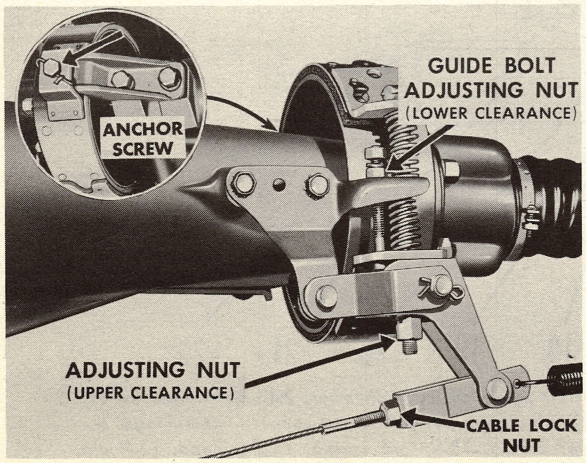
41-31. Volkswagen brakes are adjusted at the anchored end of the shoes.

The external type parking brake mounted on the propeller shaft, has the shoes anchored at the top with the adjustment for shoe clearance at the bottom.

Instead of having the parking brake on the propeller shaft, many cars use the rear wheel brakes for both service and parking. To do this, mechanical linkage is provided as shown in Fig. 41-34.

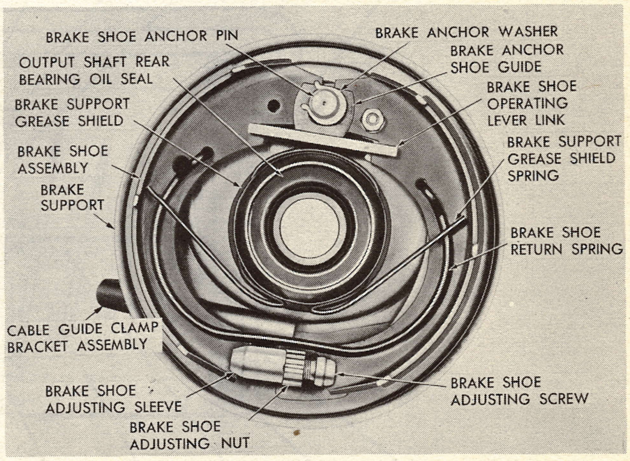

GUIDE BOLT
ADJUSTING NUT
(LOWER CLEARANCE)
ANCHOR SCREW
ADJUSTING NUT
(UPPER CLEARANCE)
CABLE LOCK NUT

41-32. External contracting type of parking or hand brake.

POWER BRAKES

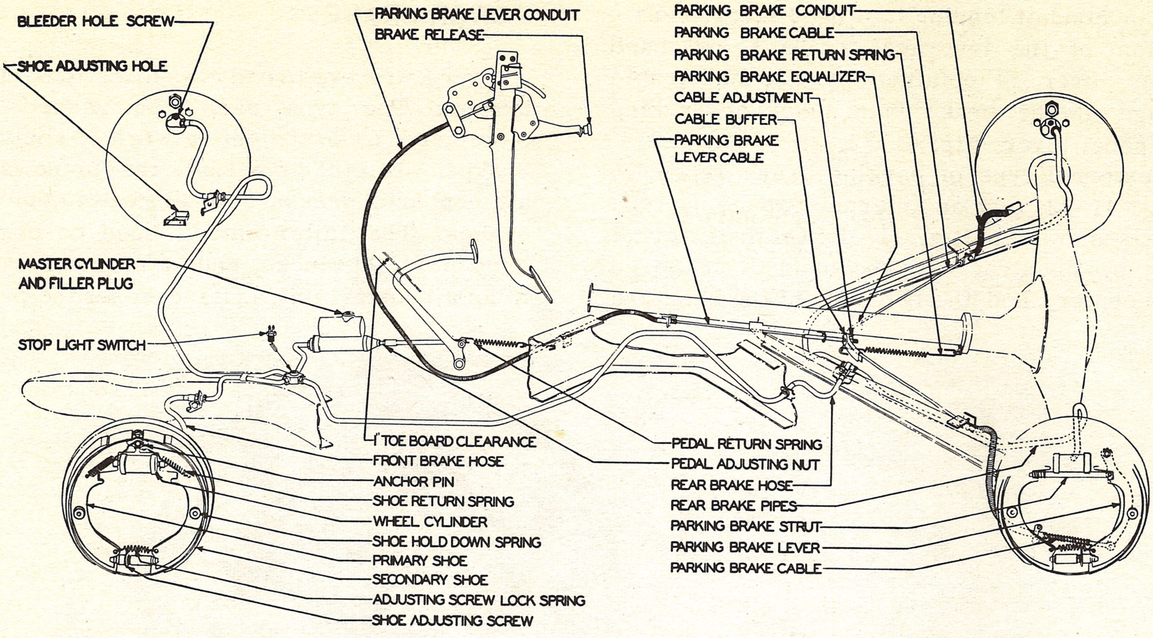
There are two broad classifications of power brakes. One type uses compressed air or electricity to do the entire work of applying the brakes. The other type uses the engine vacuum - atmospheric pressure to assist in applying the brakes. The latter unit is used on passenger cars and light trucks, and is frequently referred to as a booster unit, as it increases the pressure supplied by the driver pressing on the brake pedal.

The basic design of the vacuum atmospheric pressure type consists of a single or compound piston held in balance by either engine vacuum or air at atmospheric pressure, on both sides of the piston. These designs are known as the vacuum suspended type, and air suspended type respectively.


BRAKE SHOE ANCHOR PIN
BRAKE ANCHOR WASHER
BRAKE ANCHOR SHOE GUIDE
OUTPUT SHAFT REAR BEARING OIL SEAL
BRAKE SHOE OPERATING LEVER LINK
BRAKE SUPPORT GREASE SHIELD
BRAKE SUPPORT GREASE SHIELD SPRING
BRAKE SHOE ASSEMBLY
BRAKE SUPPORT
BRAKE SHOE RETURN SPRING
CABLE GUIDE CLAMP BRACKET ASSEMBLY
BRAKE SHOE ADJUSTING SLEEVE
BRAKE SHOE ADJUSTING SCREW
BRAKE SHOE ADJUSTING NUT

41-33. Internal expanding type parking brake. (Chrysler)

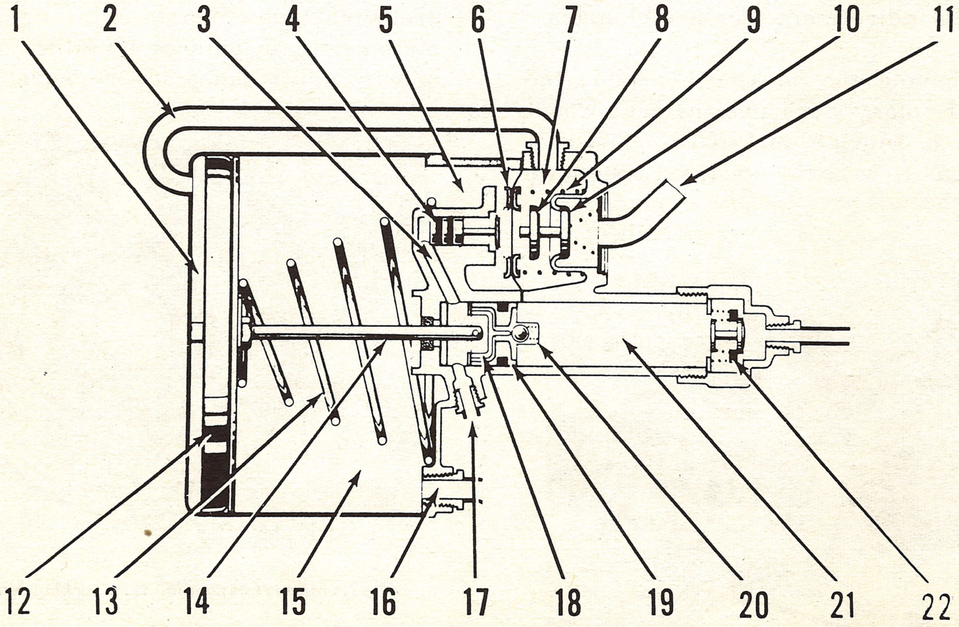
In the vacuum suspended type, Fig. 41-35,


BLEEDER HOLE SCREW
SHOE ADJUSTING HOLE
MASTER CYLINDER AND FILLER PLUG
STOP LIGHT SWITCH
PARKING BRAKE LEVER CONDUIT
BRAKE RELEASE
PARKING BRAKE CONDUIT
PARKING BRAKE CABLE
PARKING BRAKE RETURN SPRING
PARKING BRAKE EQUALIZER
CABLE ADJUSTMENT
CABLE BUFFER
PARKING BRAKE LEVER CABLE
1" TOE BOARD CLEARANCE
FRONT BRAKE HOSE
ANCHOR PIN
SHOE RETURN SPRING
WHEEL CYLINDER
SHOE HOLD DOWN SPRING
PRIMARY SHOE
SECONDARY SHOE
ADJUSTING SCREW LOCK SPRING
SHOE ADJUSTING SCREW
PEDAL RETURN SPRING
PEDAL ADJUSTING NUT
REAR BRAKE HOSE
REAR BRAKE PIPES
PARKING BRAKE STRUT
PARKING BRAKE LEVER
PARKING BRAKE CABLE

41-34. One method of hooking mechanical leverage to the hydraulic shoes for a pedal operated parking brake.

both ends of the power cylinder are connected to the engine intake manifold, thereby providing vacuum at both sides of the piston. When brakes are applied a valve is opened at one end of the power cylinder to the atmosphere, thereby allowing the atmospheric pressure of approximately 14.7 p.s.i. to push against the piston. The power piston is connected to a hydraulic piston, and the action of the power piston builds up pressure in the hydraulic lines to apply the brakes.

In the air suspended type, Fig. 41-36, both ends of the power cylinder normally are open to the atmosphere, but one end is connected to the intake manifold through a control valve. When the brakes are applied, the control valve is opened allowing air to be exhausted from one side of the piston, and thus permits air pressure to act on the other.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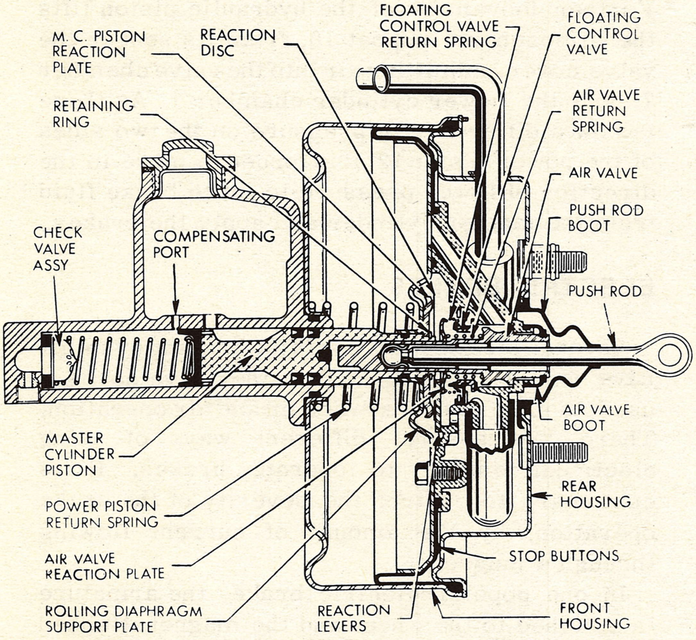
41-35. Details of vacuum suspended type of master cylinder. 1-Left power cylinder chamber. 2-Control tube. 3-Passage. 4-Valve piston. 5-Valve chamber. 6-Diaphragm chamber. 7-Valve chamber. 8-Vacuum poppet. 9-Diaphragm return spring. 10-Atmosphere poppet. 11-Atmosphere tube. 12-Power piston. 13-Return spring. 14-Push rod. 15-Right power cylinder chamber. 16-Manifold vacuum supply port. 17-Master cylinder connection port. 18-Piston yoke. 19-Hydraulic piston. 20-Ball check valve. 21-Slave cylinder. 22-Check valve.

OPERATION OF AIR-SUSPENDED TYPE

In the released position, Fig. 41-36, the air valve return spring holds the air valve, push rod, and brake pedal rearward so the air valve is clear of the floating control valve. Although vacuum is present at the floating control valve through the flexible hose, the control valve return spring holds the rubber face of the valve against its annular seat in the power piston, thereby closing off manifold vacuum.

Atmospheric air enters through the air filter into the air chamber, and flows through holes is the power piston into the reaction lever area. From here it flows past the open annular seat on the air valve, through a passage in the power piston into the vacuum chamber. With the vacuum passage closed and the vacuum chamber open to outside air, the power piston is balanced by atmospheric pressure on both sides, and is held against the rear housing by the return spring.

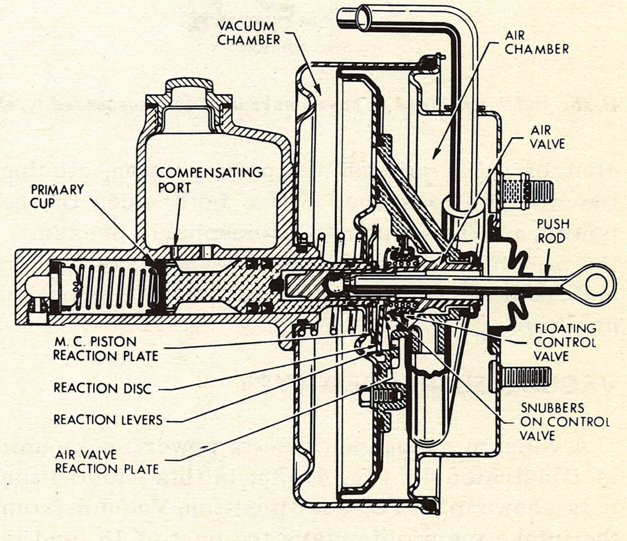

M. C. PISTON REACTION PLATE
REACTION DISC
FLOATING CONTROL VALVE RETURN SPRING
FLOATING CONTROL VALVE
RETAINING RING
AIR VALVE RETURN SPRING
AIR VALVE
PUSH ROD BOOT
CHECK VALVE ASSY
COMPENSATING PORT
PUSH ROD
AIR VALVE BOOT
MASTER CYLINDER PISTON
REAR HOUSING
POWER PISTON RETURN SPRING
AIR VALVE REACTION PLATE
STOP BUTTONS
ROLLING DIAPHRAGM SUPPORT PLATE
REACTION LEVERS
FRONT HOUSING

41-36. Air suspended type of power cylinder in the released position.

The air valve return spring and the floating control valve return spring, are holding the air valve reaction plate against the inner ends of the reaction levers. Since the outer ends of these levers are against their pivot points in the power piston, the levers are pushing forward against the reaction disks. This disk in turn, is holding the master cylinder piston and reaction plate assembly forward so that the reaction plate is against its stop. In the released position of the power cylinder, the reaction mechanism is fully forward, and the two valves are fully rearward.

As the brake pedal is depressed, the push rod moves the air valve forward until its annular seat contacts the floating control valve, at which point atmospheric pressure is sealed off from the vacuum chamber. Further movement of the air valve pushes the floating control valve away from its annular seat in the power piston, thus connecting the vacuum chamber to the vacuum source. As air is exhausted out of the vacuum chamber, atmospheric pressure in the air chamber starts moving the power piston forward, Fig. 41-37.

As the power piston moves forward, it carries the master cylinder piston into the master cylinder, building up pressure in the hydraulic system to apply the brake shoes. At the same time, a reaction pressure is transmitted back to the brake pedal to give the driver an indication of the power being applied to the brakes. As soon as pressure starts to build up in the hydraulic system, the pressure on the end of the master cylinder piston causes the master cyclinder reaction plate to move away from its stop, and press against the reaction disks and the reaction levers. The levers in turn swing around their pivots in the power piston, and push the air valve reaction plate back against the floating control valve snubbers, Fig. 41-37.

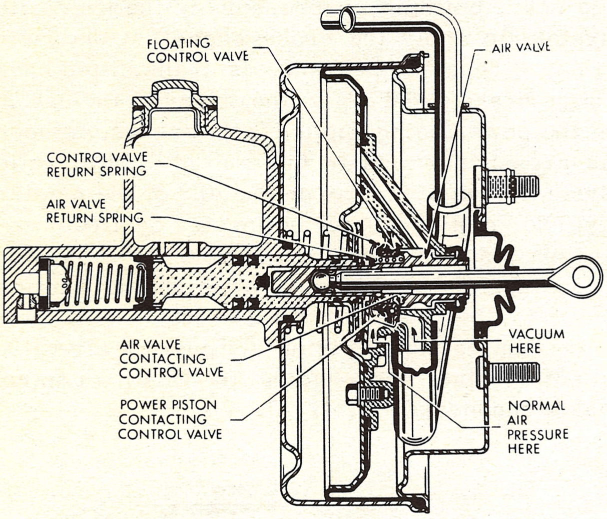

VACUUM CHAMBER
AIR CHAMBER
AIR VALVE
COMPENSATING PORT
PRIMARY CUP
PUSH ROD
M. C. PISTON REACTION PLATE
FLOATING CONTROL VALVE
REACTION DISC
REACTION LEVERS
SNUBBERS ON CONTROL VALVE
AIR VALVE REACTION PLATE

41-37. Applying position of power brake unit. (Air suspended type).

In this manner, approximately 40 per cent of the load on the master cylinder piston is transferred through the air valve and push rod to the brake pedal, to oppose the foot pressure applied by the driver.

When the desired brake pedal apply pressure is reached and the brake pedal is held still, the air valve and floating control valve are also held motionless. The power piston, however, continues forward momentarily until its annular seat contacts the floating control valve, Fig. 41-38. At this point, both the air valve and power piston are seated on the floating control valve, so the passage to the vacuum chamber is closed to atmospheric pressure as well as vacuum. As a result, the power piston is held stationary until the brake pedal is moved.

When the brake pedal is released, the air valve return spring forces the air valve away from the floating control valve. This allows the floating control valve return spring to seat the control valve against the power piston, closing the vacuum passage. Since both sides of the power are now open to atmospheric pressure, the piston return spring forces the power piston and related parts rearward to the unapplied position.



41-38. Holding position of power brake unit. (Air suspended type)

VACUUM SUSPENDED TYPE

A vacuum suspended type of power brake unit is illustrated in Fig. 41-35. In this illustration it is shown in the released position. Vacuum from the intake manifold enters the port at 16, and is transmitted to the right cylinder chamber 15, and valve chamber 5. In the released position, vacuum can pass through the center of the diaphragm assembly 6, past the vacuum poppet 8 to the valve chamber 7. Atmospheric poppet 10 is seated, preventing air from the atmospheric tube 11 to enter. Control tube 2 connects valve chamber 7 with the left cylinder chamber 1, thus providing vacuum on both sides of power piston 12.

When the brake pedal is depressed, the initial fluid pressure from the master cylinder is applied at the left of the valve piston 4, and is transmitted through the center of piston 19, to the slave cylinder 21, and past the check valve 22, to the wheel cylinder lines. Further pressure against the piston 4, overcomes the diaphragm return spring pressure 9, and the piston moves to the right. The seat at the center of the diaphragm assembly 6, contacts the vacuum poppet 8, thus closing off the vacuum passage to the vacuum chamber 7, and the power cylinder 1. Further movement of the hydraulic piston lifts the atmospheric poppet 10, from its seat in the valve cover, admitting air into the valve chamber 7, and the power cylinder chamber 1. As there is now a difference of pressure on the two sides of the power piston 12, it is forced to move in the direction of lower pressure to force brake fluid from the master cylinder and apply the brakes.

ELECTRIC BRAKES

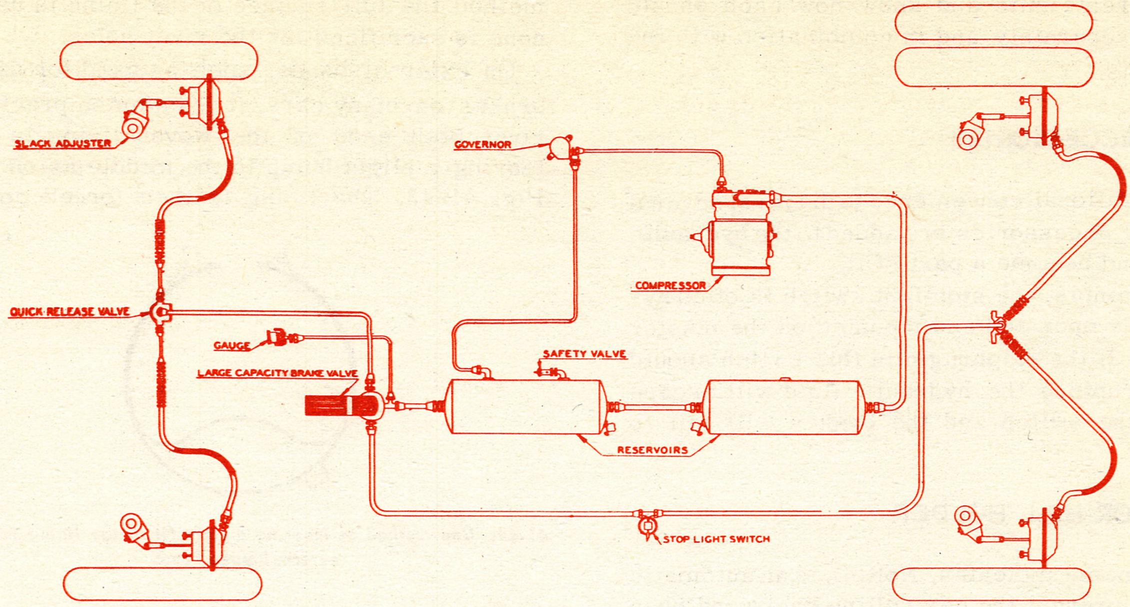
Several electrically operated braking systems have been developed. To date they have not been used as extensively as vacuum and air operation. There are several different ways of using electrical energy to operate brakes. It is customary to control the severity of the brake operation, by the amount of current flowing through a magnet.

In one popular electric brake, the armature is attached to the wheel and the magnet attached to the axle. The magnet has a lug and cam levers on it which press the brake shoe lining against the drum when current flows in the magnet. The amount of pressure applied to the lining is regulated by a foot pedal or hand lever which operates a rheostat connected to the battery.

AIR BRAKES

Air operated brakes should not be confused with vacuum boosters. Air brakes are used on trucks and heavy duty vehicles but are not necessary on ordinary passenger automobiles. An air braking system is expensive and complicated but it does prove effective for heavy duty.

The system consists of an air compressor attached to the engine, storage tanks to hold the compressed air, a governor, pressure cylinders or diaphragm chambers at each wheel, suitable control valves and the necessary piping and connections. The air may also be piped to a trailer equipped with air brakes and therefore


SLACK ADJUSTER
GOVERNOR
COMPRESSOR
QUICK RELEASE VALVE
GAUGE
LARGE CAPACITY BRAKE VALVE
SAFETY VALVE
RESERVOIRS
STOP LIGHT SWITCH

41-39. *Typical air brake layout and units required on a truck.*

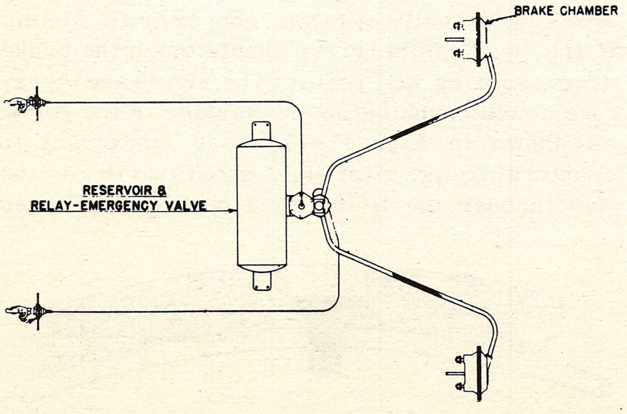
the truck driver can control the trailer as well as the truck-tractor. A typical system is illustrated in Figs. 41-39 and 41-40. Fig. 41-41 shows the construction of a typical power cylinder.

COMBINATION OF UNITS

It now becomes apparent that we can have various combinations of units to fit different conditions.

We have passenger cars with either mechanical or hydraulic brakes and with or without vacuum boosters.

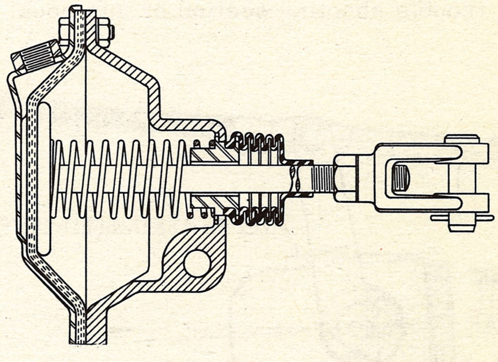
We have trucks with electric brakes or with either mechanical or hydraulic brakes that use vacuum boosters, vacuum power operation or air power operation.


BRAKE CHAMBER
RESERVOIR &
RELAY-EMERGENCY VALVE

41-40. *As used on a two wheel trailer this air brake is connected to the truck-tractor system.*

We have trailers with electric brakes or with mechanical or hydraulic brakes operated by either air power or vacuum power.

Also all sorts of combinations of these different units. For example a Diesel truck which has no intake manifold vacuum may be equipped with air operated mechanical or hydraulic brakes. Perhaps it is desired to pull a trailer that is equipped with vacuum operated mechanical or hydraulic brakes. In this case we will have to provide the truck with a vacuum pump in order to operate the trailer brakes.



41-41. *This cross-section shows the construction of a typical power brake application cylinder.*

There are dozens of combinations of different units in this fashion. Furthermore air cylinders or diaphragms are combined with hydraulic cylinders in one unit, etc., etc. For these reasons the brake serviceman must understand all of the different units and know how each should function separately and in combination with the other units.

BRAKE ACCESSORIES

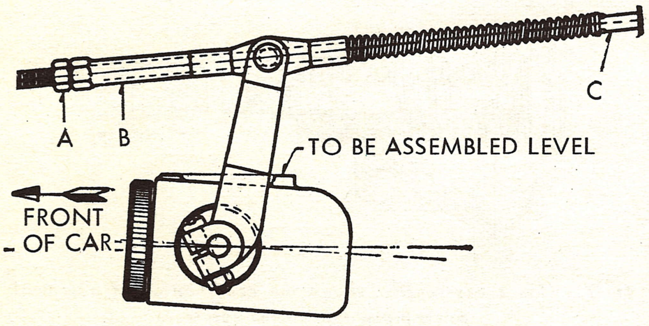
For additional convenience to drivers, several automatic accessories are added to the hydraulic system and become a part of it.

For example, the stoplight switch is often hydraulically operated and mounted on the master cylinder. If the diaphragm in this switch should leak or rupture the hydraulic fluid will escape through the switch and the brakes will fail to operate.

NO ROL OR HILL HOLDER

As its name indicates, NoRoL, is an automatic device to prevent the car rolling backward when it is stopped on an upgrade. It consists of a valve that is controlled by the angle of the car and the clutch pedal to which it is connected. The valve sets at an angle and when the clutch pedal is depressed with the car on an upgrade a ball rolls by gravity and seals the pressure in the brake system after the brakes are applied and until the clutch is released.

If the car is level or on a downgrade the device does not operate. The device is illustrated in Fig. 41-42. Adjustments are covered in the trouble shooting section of this book.



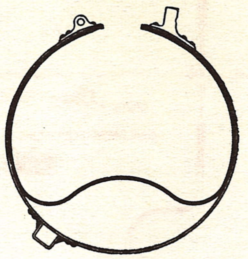
41-42. The NoRol unit is mounted on the car at a slight angle as gauged by the bosses on top of the housing.

BRAKE SERVICE

ATTACHING BRAKE LINING

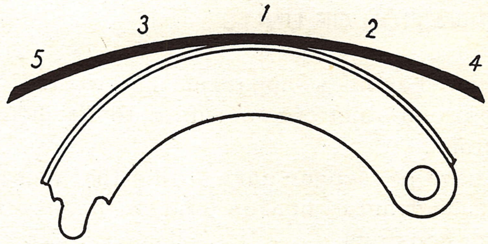
There are two general methods of attaching brake lining to brake bands or brake shoes; by using rivets, and by bonding. With riveting it is considered there is less possibility of the lining coming loose, while with the bonding method the full surface of the lining is used as none is sacrificed for the rivet holes.

On external bands, such as used for parking brakes on many cars, it is common practice to rivet both ends of the woven lining in place leaving a slight hump in the middle as shown in Fig. 41-43. The lining is then forced down in place so it fits snugly against the metal brake band.



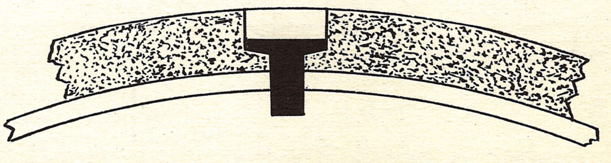
41-43. One method of insuring a tight fit of the lining inside an external brake band.

On internal expanding brake shoes, where molded lining is used, it is advisable to use a special brake lining clamp to force the lining down tightly against the brake shoe at all points. If such a clamp is not available, the next best method is to rivet in the middle, and work out to the ends as shown in Fig. 41-44.



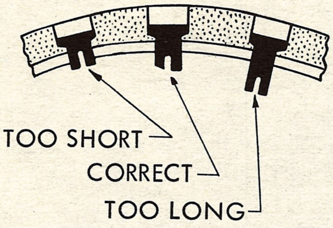
41-44. The rivets should be placed first in the middle, then at 2, 3, 4 and 5 when riveting lining to a shoe unless a suitable clamp is available.

Rivets used in fastening brake lining to brake shoes are usually of brass, copper or aluminum. If the head of the rivet should touch the brake drum, scoring will result. The rivets are therefore countersunk below the surface of the lining as shown in Fig. 41-45. It is customary to countersink the rivet hole about two thirds the way through the lining. The countersunk holes



41-45. Countersink hole in lining should be accurate to the size and shape of the rivet.

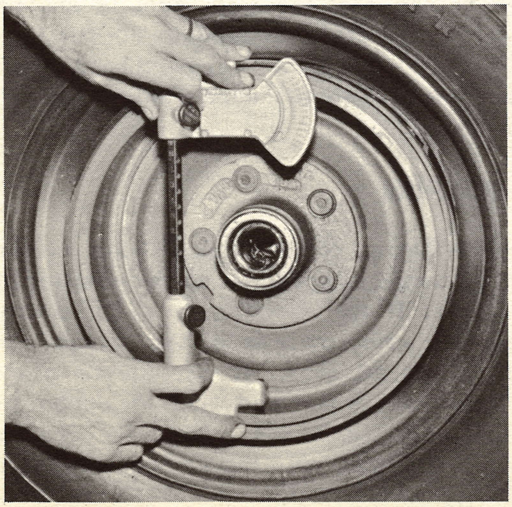
should be exactly the same size as the rivet head for greatest strength, and the rivet hole in the lining should be the same size as the hole in the brake shoe. It is, of course essential that the rivet fit snugly in the rivet hole and be of the right length to "upset" smoothly and easily. A good rule for rivet length is to have the rivet extend through the hole about two thirds of the rivet diameter. For example, a 3/16 in. rivet should have a 1/8 in. shank sticking out for riveting over, Fig. 41-46.



41-46. Rivets should be set with a roll punch instead of a star punch.

In bonding brake lining to the shoes, a cement is used between the shoes and the lining. The lining is then clamped tightly, and placed in a special oven for curing. The cement can be applied to the lining in the form of a paste, or in the form of a tape interposed between the lining and the shoe.

Before applying new lining to a shoe, it is essential that the surface of the shoe be perfectly clean. This is essential, whether the new lining is to be riveted in place or bonded. Special sanders are available for cleaning the shoes so the new lining will adhere tightly to the shoe, and there will be a minimum of resistance to the transmission of the heat of braking.

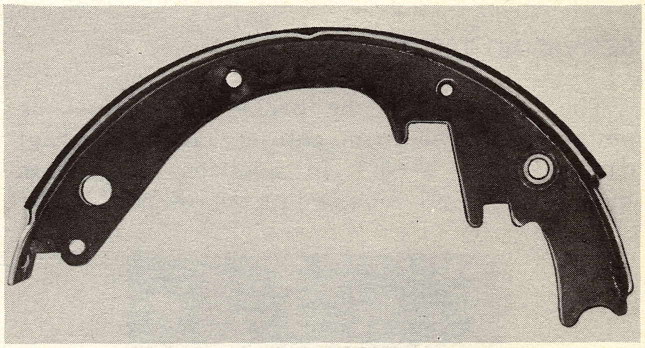


41-47. Checking a brake drum with a special gauge, for diameter, bell-mouth condition and out-of-round.

PREPARATION OF SHOES

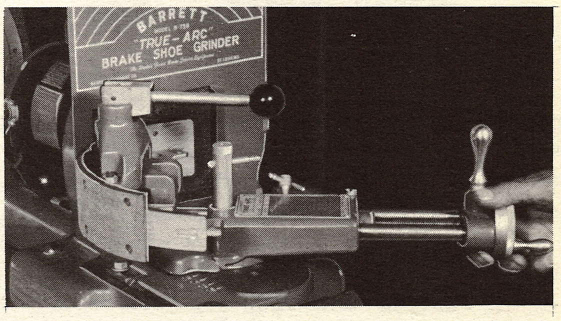
Before relining brakes it is important to make sure that the diameter of the brake drum is standard, Fig. 41-47. If the brake drum has been reconditioned it will be larger in diameter. If the diameter has been increased more than .030 in., lining of oversize thickness should be installed.

The surface of the brake lining of newly relined shoes does not conform accurately to the surface of the brake drum. New lining has slight high and low spots. In addition, the brake shoes may be bent or warped, Fig. 41-48. Or if the drum has been reconditioned, it will be slightly larger in diameter and will not conform to the arc of the brake shoes.



41-48. Note that most of the wear is at the center of the brake shoe and very little at the ends, indicating a warped brake shoe.

Brake shoes should therefore be sanded with special brake shoe sanding equipment, Fig. 41-49, not only to smooth the surface, but so it will conform to the curvature of the brake drum.



41-49. Sanding the surface of a brake shoe.

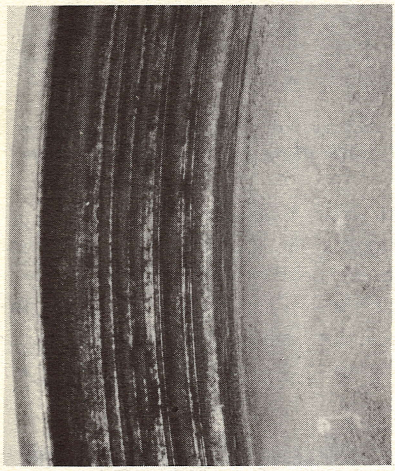
Such sanding equipment will provide a smooth even surface. If the shoes are used without such sanding, the high spots of the lining will do all the braking, and much higher temperature than normal will result. Such high temperatures will quickly ruin the new lining and in addition, the brakes may become heat checked.

Care must always be exercised that no grease or oil reaches the brake lining, as that will affect the coefficient of friction and grabbing brakes will result. In that connection, it is always good policy to install new grease seals whenever new brake lining is installed. Also wheel cylinders should be examined to make sure they are not leaking. When handling brake shoes, care must be taken that the hands are not greasy.

When lubricating the front wheel bearings, only grease specified for that purpose should be used, and only enough applied to lubricate the bearing. Excess lubricant may get on the brake lining and ruin it.

SERVICING THE DRUMS

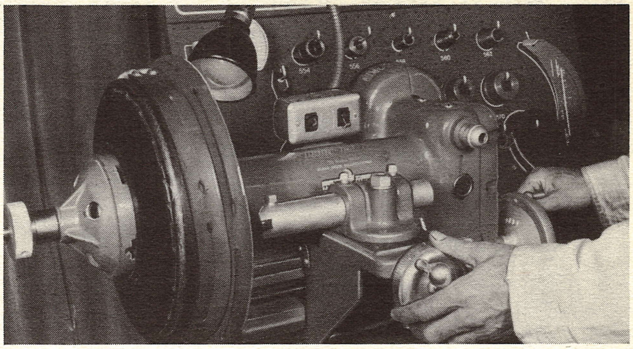
The surface of the brake drum must be smooth and free from galling, ridges and heat checks, Fig. 41-50. In addition, the drum must not be bell-mouthed or out-of-round. The ridges, galling and check marks are easily visible, but a drum gauge should be used to check for the other conditions. Fig. 41-47 shows a modern brake drum gauge. The manner in which the brake lining is worn on the shoe will also indicate the condition of the drum, as a drum that is bell-mouthed will cause the lining to wear more on one side of the shoe than on the other.



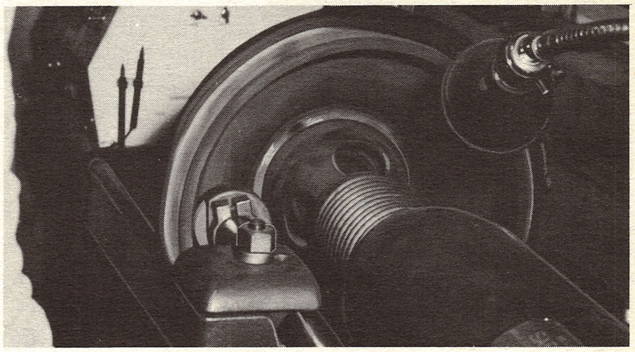
41-50. Badly scored brake drum.

An important reason for checking the diameter of the drum, is to note whether there is enough metal to permit reconditioning. Passenger car brake drums should not be reconditioned to more than 0.060 in. oversize. More than that amount will severely weaken the drum. Not only will the drum become oval when the brakes are applied, but because of less metal, the drum will operate at much higher temperatures, with attendant brake fade and short lining life.

Brake drums can be reconditioned either by turning on a lathe, Fig. 41-51, or by grinding, Fig. 41-52. Both methods are used extensively. The regrinding method is used particularly in cases where the drum has hard spots.



41-51. Reconditioning a brake drum by turning on a brake drum lathe.



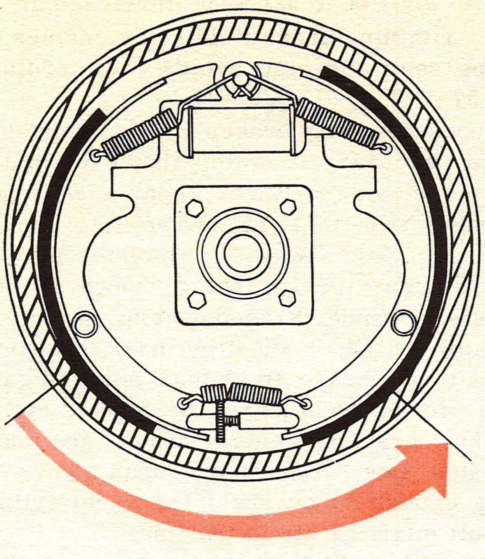
41-52. Grinding a brake drum.

When turning a drum on a lathe, care must be exercised that the lathe tool is sharpened correctly, and the tool feed is not too fast, as that would result in a "screw thread" type of surface which would cause rapid wear of the brake lining.

ANCHOR PINS

Centralization of the brake shoes within the drum, is largely dependent on the position of the anchor pin. If the anchor pin is not correctly placed, the effectiveness of the brakes will be greatly reduced. Fig. 41-53, shows how the effective force is reduced when the anchor pin is too low and Fig. 41-54, shows the results of having it too high, with the strong possibility of grabbing condition. Fig. 41-55 shows how the servo action of the brake is built up smoothly and rapidly, when the anchor pin is correctly

Brake shoes low on anchor
(Arrow shows effective force)



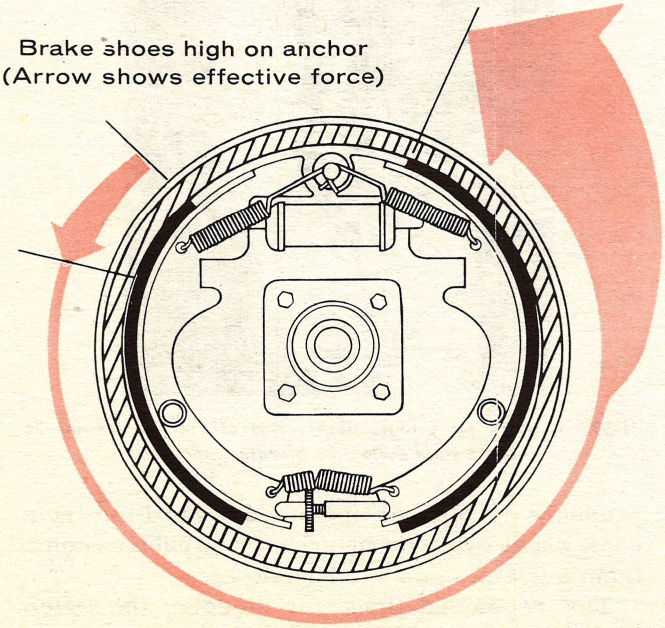
41-53. Unless anchor pins are correctly located, full braking will not be attained. Here the anchor pin is too low.

located. On those brakes which have adjustable anchor pins, care should therefore be taken to adjust the anchor pin correctly.

HYDRAULIC SERVICE

No hydraulic brake system can operate satisfactorily unless the various parts are in good mechanical condition and the system full of CLEAN fluid of the proper type. Lubricating oil or mineral hydraulic oil is not the proper type. Mineral oil of any kind will swell and ruin the rubber cups and other parts of the system. Furthermore, it does not have the proper viscosity characteristics for use in an automobile.

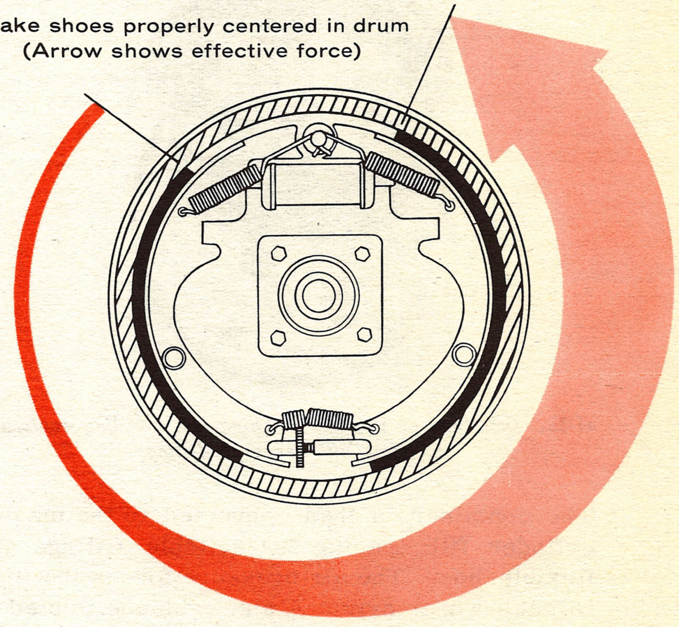
Brake shoes high on anchor
(Arrow shows effective force)



41-54. Grabbing brakes result when anchor pins are too high.

The fluid MUST be CLEAN. Any dirt is liable to get in the valves and cause them to leak. Furthermore, adding clean fluid to dirty fluid means dirty fluid. Therefore if there is any doubt about dirt being in the system it should be drained out and flushed. Equipment and material are available for flushing out hydraulic systems and their use will avoid clogging of ports, sticking valves, leaking and scored cylinders and erratic brake action. In addition periodic flushing will remove any gum from the old fluid, condensed moisture, bits of scale and rubber, etc.

Brake shoes properly centered in drum
(Arrow shows effective force)



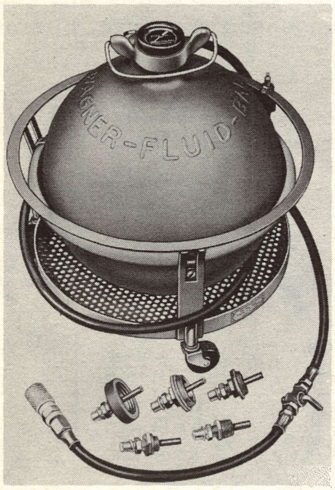
41-55. Smooth, even braking results when anchor pins are set correctly.

Before adding new fluid, if the car is old, it is well to inspect the flexible lines or hose to make sure that they are not weakened, frayed or swollen inside. All connections and fittings should be checked for leaks and to make sure that the pipe lines are securely fastened to the frame to avoid vibration and eventual breakage. Sometimes lines will also get kinked or dented or worn thin from some other part rubbing on them. If defective in any way they should be replaced.

If the master cylinder and wheel cylinders are known to be in good condition, the fresh fluid can then be added and the system "bled" to remove all air. If there is any air in the system, the pedal will have a "spongy" feel as the hydraulic pressure is compressing the air in the system. When the brakes are applied the pedal should be solid as the hydraulic fluid does not compress.

BLEEDING BRAKES

There are two general methods in use for bleeding hydraulic brake systems. The manual method requires two men and is slower than pressure bleeding. Pressure bleeding has other advantages but involves the use of special equipment. This equipment consists of a closed, airtight container which contains brake fluid to which air pressure is applied. See Fig. 41-56.



41-56. One type of pressure flushing and bleeding equipment complete with necessary fittings.

The container is then connected to the master cylinder fill opening by suitable fittings and flexible hose. The air pressure forces the fluid to each wheel cylinder and each one is bled in turn by opening the bleeder valve and closing it when the fluid is clear and bubbles no longer appear.

This equipment can also be used for flushing out the system when desired by using a flushing fluid instead of brake fluid. In addition to one man operation and faster operation there is no loss of fluid from spillage and no air can get in the system. Furthermore if the fill plug opening and the area around it is thoroughly cleaned before the plug is removed and the hose connected, no dirt can fall into the master cylinder.

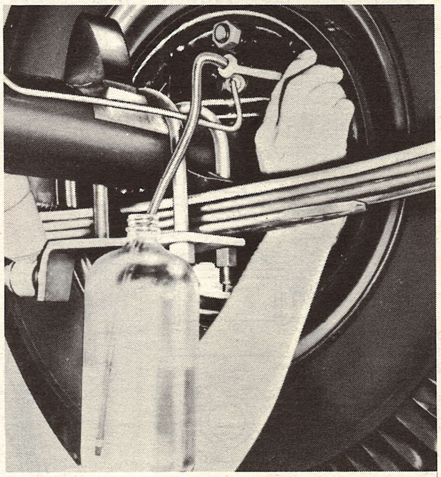
When the manual method is employed, one man "pumps" the pedal to force the fluid through the lines and the other man bleeds the brakes. The first one bled is the farthest from the master cylinder, in most cases the right rear. Next the left rear, then the right front and lastly the left front. With either power or manual bleeding, a hose is attached to the bleeder valve and the other end immersed in a glass jar containing brake fluid. This enables bubbles to be seen and also avoids waste of fluid, Fig. 41-57.

When bleeding brakes by the manual method it is necessary to watch the level of the fluid in the master cylinder because if it gets low enough, air will be drawn into the master cylinder. Other ways in which air may get into the system include being drawn in around a master cylinder secondary cup, any repair to a master cylinder, wheel cylinder, hose or tubing. Sometimes brake fluid may boil and gas in the lines in hot weather if the master cylinder or brake lines are located too near the muffler or exhaust line. Also if one brake were to drag long enough to overheat the wheel cylinder the result might be air in the line.

After bleeding, the reservoir should be checked and the fluid at a level one-half inch from the top of the reservoir. Also it is wise to check the breather ports in the filler plug to make sure they are not plugged.

Bleeding Split-System Master Cylinder:

When bleeding a brake system equipped with a split-system master cylinder as manufactured by Bendix, the procedure is to remove both master cylinder bleeder caps and connect a bleeder hose to the front reservoir. Install a solid filler cap on rear reservoir. Build up pressure in bleeder and bleed brake fluid from each wheel cylinder in turn until no bubbles come from system. See Fig. 41-16a.



41-57. A glass jar permits observation of the bubbles in the brake fluid during the bleeding process.

The recomendations for bleeding the Delco split-system master cylinder system is to connect the bleeder hose to the front master cylinder reservoir. Build up pressure in the bleeder and bleed both of the rear wheel cylinders, in the usual manner. Then connect bleeder hose to rear master cylinder reservoir, and repeat the bleeding procedure on the front wheel cylinders.

CHECKING HYDRAULIC CYLINDERS

When any work is needed on either the master cylinder or wheel cylinders, it must be done with a high degree of accuracy and absolute cleanliness is of utmost importance. Of course solvents or gasoline should not be used to clean the boots, cups, check valve assembly or any rubber parts. Alcohol is the proper cleaning fluid. The metal parts may be cleaned in solvent if they are then rinsed in alcohol.

The compensating port in the master cylinder must be open and this can be checked by pushing a very small gauge wire through it. The cylinders must be free of scratches, grooves or pits and should be measured to make sure that they have not been honed oversize. If it is oversize it will be necessary to replace it, install a sleeve in it or use an oversize piston.

If the cylinder is not oversize but is rough, it can be polished with a special hone made for the purpose. After honing, the by-pass port should be reamed with a special burr removing tool to make sure there will be no sharp edge around the hole which might scratch the primary cup as it moves back and forth within the cylinder.

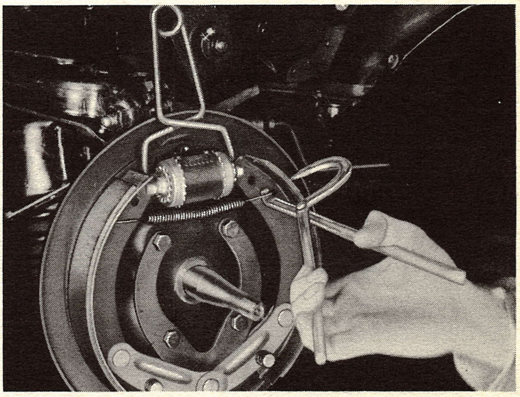
Before reassembling, all parts should be washed in clean alcohol and dipped in brake fluid. Ordinary gasoline, kerosene, solvents and cleaning fluids should never be used.

When installing the master cylinder, it is important that the piston rod be adjusted properly so that the edge of the piston cup does not cover the compensating port. If there is any doubt a small wire can be inserted into the compensating port through the fill cap opening with the brake pedal in the released position when the adjustment is correct.

If this port is covered with the pedal in the released position, the fluid cannot return from the lines to the reservoir. This will cause the brakes to drag as previously explained.

The rubber boot that fits around the push rods should be firm and fit snugly at both ends to prevent the entry of dust or dirt which would score the piston.

The wheel cylinders also have rubber boots on them to keep dirt out of the wheel cylinders. These too must be in good condition and fit snugly. If these boots should leak, brake fluid might get on the brake lining and cause the brakes to grab. Put clamps on the wheel cylinders as shown in Fig. 41-58 before removing the retractor springs from the shoes; otherwise the wheel cylinder cups may move outward and cause air to enter the system. This would necessitate bleeding the brakes.



41-58. A special clamp should be placed on the hydraulic wheel cylinder before the brake shoe return spring is removed. Otherwise the cups may move outward and permit air to enter the cylinder.

BRAKE TROUBLE SHOOTING ✓

SYMPTOM OR PROBABLE CAUSE	PROBABLE REMEDY
PEDAL SPONGY ✓	
1. Air in brake lines	1. Bleed brakes
ALL BRAKES DRAG ✓	
1. Mineral oil in system	1. Flush entire system and replace all rubber parts
2. Improper push rod to main cylinder piston clearance	2. Overhaul master cylinder

ONE BRAKE DRAGS

1. Loose or damaged wheel bearing	1. Adjust or replace wheel bearings
2. Weak, broken or unhooked brake shoe return spring	2. Replace retractor spring
3. Incorrect parking brake adjustment	3. Readjust parking brake at equalizer
4. Damaged or frozen parking brake cable	4. Free-up or replace parking brake assembly

EXCESSIVE PEDAL TRAVEL

1. Normal lining wear or improper shoe adjustment	1. Adjust brakes
2. Fluid low in master cylinder	2. Fill master cylinder to correct level

PEDAL GRADUALLY GOES TO FLOOR WHEN BRAKES ARE APPLIED

1. External fluid leaks	1. Check master cylinder and wheel cylinder for leaks. Check brake lines for leaks
2. Master cylinder leaks past primary cup	2. Overhaul master cylinder

BRAKES UNEVEN

1. Grease on lining	1. Replace lining and correct cause of grease getting on lining
2. Tires improperly inflated	2. Inflate tires
3. Front suspension faulty	3. Correct alignment
4. Rough turned brake drum	4. Have drum finish turned

EXCESSIVE PEDAL PRESSURE

1. Grease or water on lining	1. Clean or replace lining
2. Full area of lining not contacting drums	2. Adjust anchor pin. Replace shoes
3. Scored brake drums	3. Turn drums and install new shoes

PEDAL HOP

1. Drums out-of-round	1. Replace drums

BRAKE FADE

1. Defective master cylinder	1. Overhaul master cylinder
2. External fluid leaks	2. Locate and repair
3. Vapor lock	3. Flush and refill hydraulic system with quality fluid
4. Thin brake drums	4. Install new brake drums

DIVING

1. Shoes not centered	1. Adjust anchor pins
2. Primary and secondary shoes reversed	2. Install shoes correctly

BRAKE CHATTER

1. Loose brake lining	1. Install new lining
2. Shoes not centered	2. Adjust anchor pins
3. Rough turned brake drum	3. Finish turn brake drum

QUIZ - BRAKES

1-What is friction?

2-Friction is the same for all materials.
  a. True
  b. False

3-If the area between two contacting surfaces is increased, what happens to the friction?
  a. It increases
  b. It decreases
  c. Remains the same

4-How is the coefficient of friction calculated?

5-If the weight of a vehicle is doubled, will the amount of heat developed in braking be twice as much, or four times as much?

6-If the speed of a car is increased from 30 m.p.h. to 60 m.p.h., will the heat developed in stopping, be twice as much or four times as much?

7-Define reaction time as applied to applying brakes.

8-Give the formula used in calculating the kinetic energy developed in stopping a car.

9-List five factors that tend to increase brake temperatures.

10-When will the fastest stops be made? With the wheels rotating or with the wheels locked.

11-Is the hydraulic pressure in a brake system the same through the entire system or does it vary?

12-How is the force in an hydraulic brake system multiplied?

13-If the pressure provided by master cylinder is 500 p.s.i., what is the total pressure at a wheel cylinder of 2 sq. in. area?
  a. 500 lb.
  b. 1000 lb.
  c. 2000 lb.

14-What is meant by the term weight transfer?

15-List five factors that contribute to the effectiveness of brakes.

16-Describe self-energization.

17-Which brake will have the greater self-energization? One with the anchor pin nearer the center of rotation or one with the anchor pin far from the center of rotation.

18-List the two main types of brake lining materials.

19-What material is used mostly for the braking surface of brake drums?
  a. Cast iron
  b. Wrought iron
  c. Steel

20-What is the advantage of using aluminum in a brake drum?

21-Describe the operation of a hydraulic brake system.

22-What is meant by the term split system master cylinder?

23-List five qualities that a good hydraulic brake fluid must meet.

24-What is the purpose of the check valve in the master cylinder?

25-Under extreme conditions, what temperature may be expected in the brakes?
  a. 700 deg.
  b. 100 deg.
  c. 2000 deg.
  d. 950 deg.

26-What causes vapor lock in a brake system?

27-Where is there the greater tendency toward vapor lock?
  a. On top of a mountain
  b. At sea level

28-On a conventional Bendix single anchor brake where it is desired to expand the shoes in the drums, how should the handle of the adjusting tool be moved?
  a. Upward
  b. Downward

29-How many wheel cylinders are used on the front brakes of the Lockheed hydraulic brakes?
  a. One
  b. Two

30-Are the operating temperatures of the disk or caliper type brake as used on many European cars, higher or lower than on brakes of the conventional drum type?
  a. Higher
  b. Lower

31-What is meant by the vacuum suspended type of power brake unit?

32-What is meant by the air suspended type of power brake unit?

33-When riveting brake lining to a brake shoe, how far should the hole be countersunk into the lining?
  a. 1/3
  b. 1/2
  c. 2/3

34-Give one advantage of bonded lining over riveted lining.

35-When should oversize lining be installed on brake shoes?

36-What is the limit in oversize when reconditioning brake drums?
  a. .060 in.
  b. .125 in.
  c. .030 in.
  d. .006 in.

37-Why must care be exercised when setting the adjustable type of anchor pin?

38-What results will happen if mineral oil is used in an hydraulic brake system?

39-Describe the procedure for bleeding brakes.

40-When cleaning hydraulic brake parts, what type cleaning fluid should be used?
- a. Alcohol
- b. Good grade of cleaning solvent
- c. Kerosene

CLUTCHES

As previously explained in the engine section of this text, it is characteristic of an internal combustion engine to develop little power or torque at slow rotational speed. It is also well known that more effort is required to start a body in motion than to keep it moving once it is in motion.

Therefore it is desirable to allow the engine to attain increased speed of rotation before it is required to put the automobile, truck or tractor in motion. Obviously, a sudden connecting of the rapidly rotating engine to the propelling means of the stationary vehicle would result in violent shock.

Gradual application of the load along with some slowing of the engine speed is needed to provide reasonable and comfortable starts. For this purpose many types of connecting means have been used as a coupling between the engine and driving wheels.

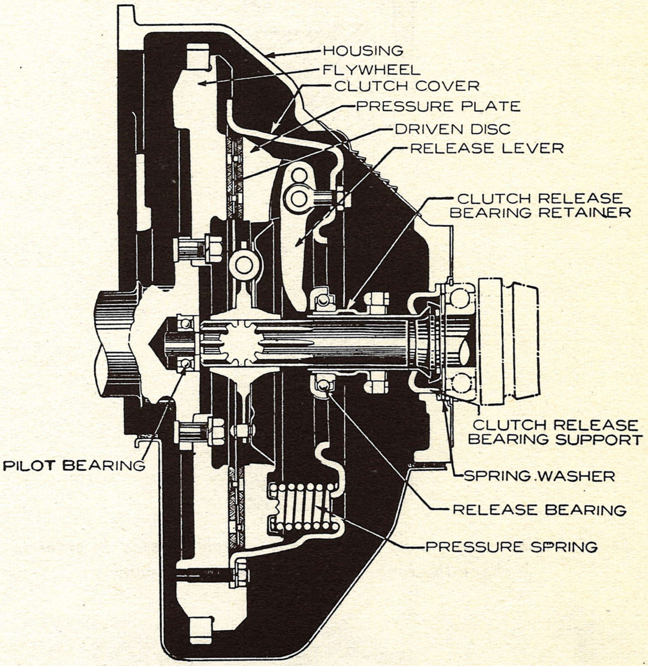
These devices are of mechanical, electrical and hydraulic types. The electrical, hydraulic and some mechanical types are described in the transmission section of this text. Herein we will deal with the mechanical types of clutches.

SINGLE PLATE CLUTCHES

Most modern clutches have a single plate with a fabric facing on each side but some heavy duty plate clutches have two such plates or discs. In both cases the disc or discs are positioned between the flywheel and a solid plate known as a pressure plate. See Fig. 42-1.

The flywheel surface upon which the fabric facing bears must of course be flat and true as well as free from ridges or cracks. The same applies to the clutch pressure plate which bears on the clutch facing or fabric on the other side of the clutch plate.

If either of these surfaces are warped, cracked or damaged they can be resurfaced by grinding or turning in a lathe. The pressure plate can be checked for warpage with a feeler gauge and surface plate as shown in Fig. 42-2. The flywheel face can be checked by means of a dial gauge mounted on the housing as shown in Fig. 42-3.



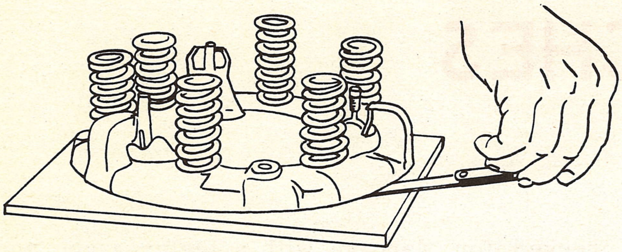
42-1. Typical single plate clutch assembly.

CLUTCH DISCS

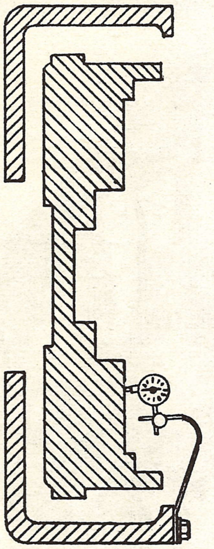
While it is essential that both metal surfaces, as just described, be flat and true this does not necessarily apply to the friction surfaces of the clutch disc or plate. In some cases the facing or disc or both are purposely warped as shown in Fig. 42-4. This is done to encourage "soft" engagement. When the clutch is fully engaged the clutch spring or springs press the disc and facings flat between the flywheel and pressure plate.

Other clutch plates are flat as shown in Fig. 42-5.

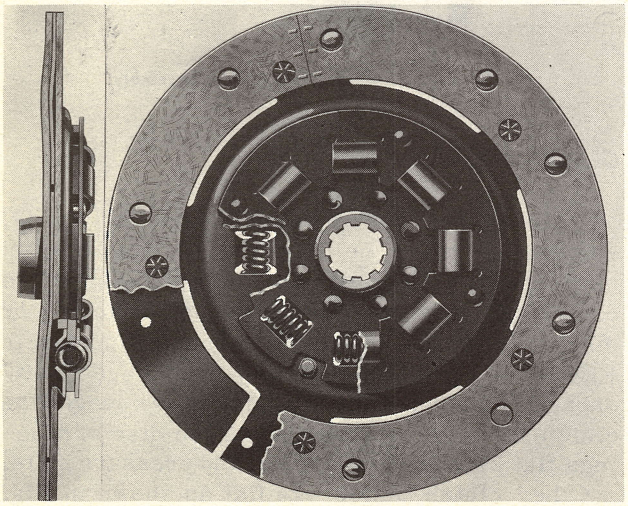
Where two clutch discs are used, they are usually fastened together as shown in Fig. 42-6. The flywheel, the intermediate plate and the pressure plate are also made to rotate together but are mounted in such manner that the pressure plate and intermediate plate can move into and out of engagement as shown.



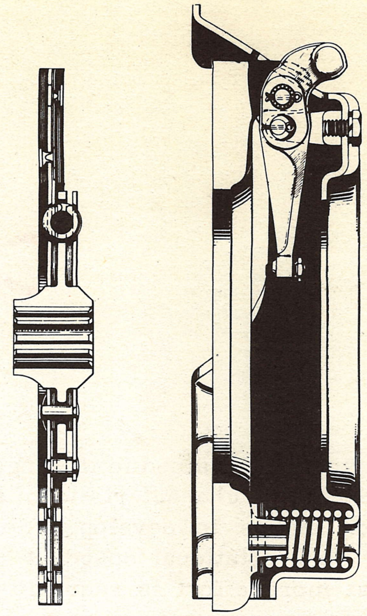
42-2. *Method of checking clutch pressure plate for warpage.*



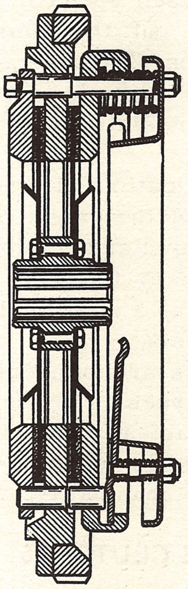
42-3. *A dial gauge is mounted on the clutch housing in order to check the face of the flywheel for run-out.*



42-4. *Segments of the clutch disc rim are often arched to provide gradual engagement.*



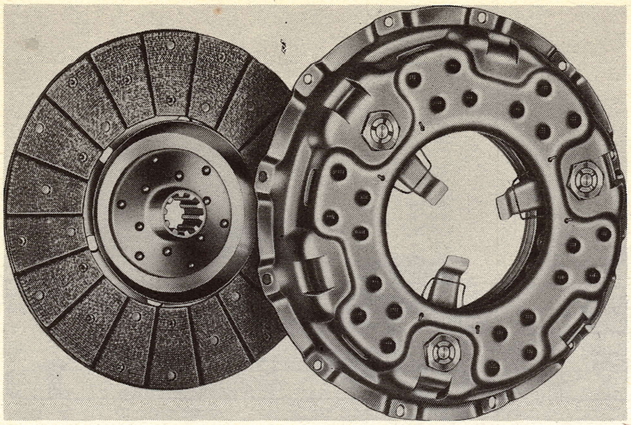
42-5. *Some clutch discs are completely flat.*



42-6. *Dual clutch discs are fastened together at the hub and have a pressure plate on each side.*

DISC FACINGS

Most clutch friction facings are made of woven or molded asbestos and are riveted or bonded to the clutch disc. See Fig. 42-7. It is important that the friction surface be smooth and the thickness of the plate assembly quite uniform. It is desirable to keep any trace of grease or oil from the friction surface. Actually a greasy thumb print on the friction surface may result in "grabbing" or chattering of the clutch.



42-7. In this case, the disc facings are in segments.

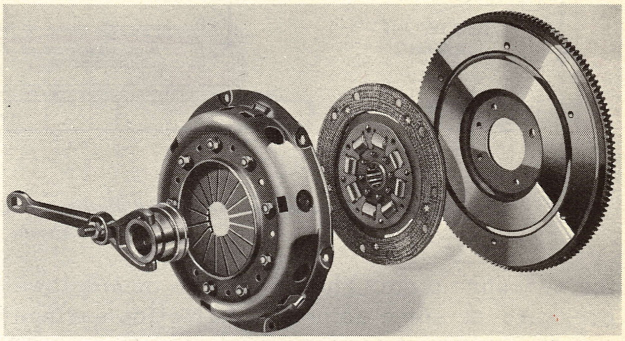
CLUTCH SPRINGS

Several different types of springs are used to hold the pressure plate against the disc and in turn the disc against the flywheel. One widely used type is illustrated in the disassembled view Fig. 42-8. The exploded view in Fig. 42-9 shows each of the parts more clearly.

This type of spring is known as a diaphragm spring and is in the shape of a dished plate. It is important to understand just how this spring operates. This is illustrated diagrammatically in Fig. 42-10. Also see Fig. 42-11.

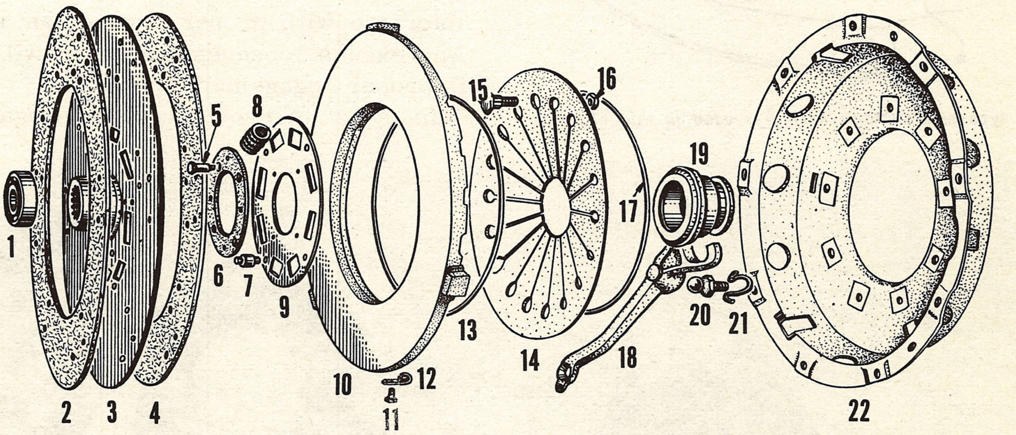
MULTIPLE SPRINGS

Many clutches use several small coil springs rather than one or two large springs. See Fig. 42-12. In this case the small springs are spaced around the pressure plate inside a clutch cover. The cover is bolted to the flywheel and the spring pressure is exerted between the pressure plate and the cover.



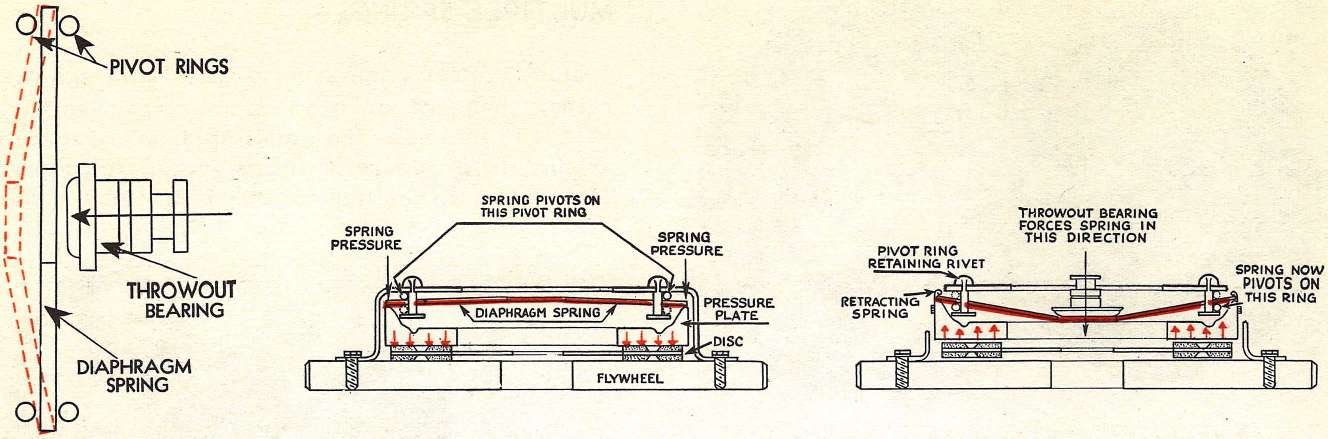
42-8. A diaphragm or dished type of spring is used in this design to hold the pressure plate against the disc facing.

In any case where multiple springs are used, it is important that the springs be equal in length and strength. If one spring be shorter or longer than the others, or if it is weaker or stronger than the others it will be difficult for the disc to seat evenly between the flywheel and



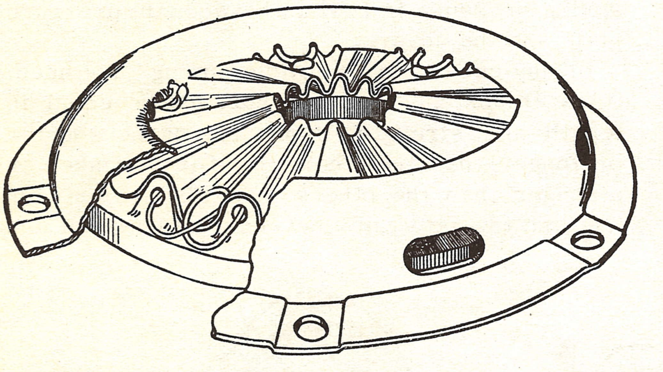
1. Pilot Bearing
2. Facing
3. Disc
4. Facing
5. Dampener Spring Plate Rivet
6. Dampener Spring Outer Plate
7. Driven Member Stop Pin
8. Dampener Spring
9. Dampener Spring Plate
10. Pressure Plate
11. Retracting Spring Bolt
12. Pressure Plate Retracting Spring
13. Spring Ring
14. Clutch Spring
15. Spring Retainer Bolt
16. Spring Retainer Bolt Nut
17. Spring Ring
18. Release Yoke
19. Release Bearing and Support Assembly
20. Release Yoke Ball
21. Ball Retainer
22. Cover

42-9. This exploded view shows the various parts of a diaphragm spring clutch completely disassembled.


PIVOT RINGS
THROWOUT BEARING
DIAPHRAGM SPRING
SPRING PIVOTS ON THIS PIVOT RING
SPRING PRESSURE
SPRING PRESSURE
DIAPHRAGM SPRING
PRESSURE PLATE
DISC
FLYWHEEL
THROWOUT BEARING FORCES SPRING IN THIS DIRECTION
PIVOT RING RETAINING RIVET
RETRACTING SPRING
SPRING NOW PIVOTS ON THIS RING

42-10. Pivot rings are used to give the diaphragm spring an over-center action in applying and releasing pressure as shown in these diagrams.

the pressure plate. This of course means lower pressure at some point of the friction surfaces which may result in slippage. See Fig. 42-12. Special tools are available for checking spring strength.



42-11. Another type of diaphragm spring is used in this clutch.

CLUTCH HUBS

It is essential that the clutch disc slide freely on the shaft so as to permit complete and rapid engagement and disengagement. At the same time it is desirable that no looseness exist between the clutch hub and shaft. In order to meet these requirements the hub is usually splined to the shaft rather than keyed or otherwise attached. See Fig. 42-13.

These splines on hub and shaft must be made very accurately so that the fit will be snug yet free. Any scratches on the splines or any rust accumulation will cause the disc to stick and interfere with proper engagement and release. Any excess looseness or wear will also cause improper engagement and noise.

In order to provide smooth engagement and

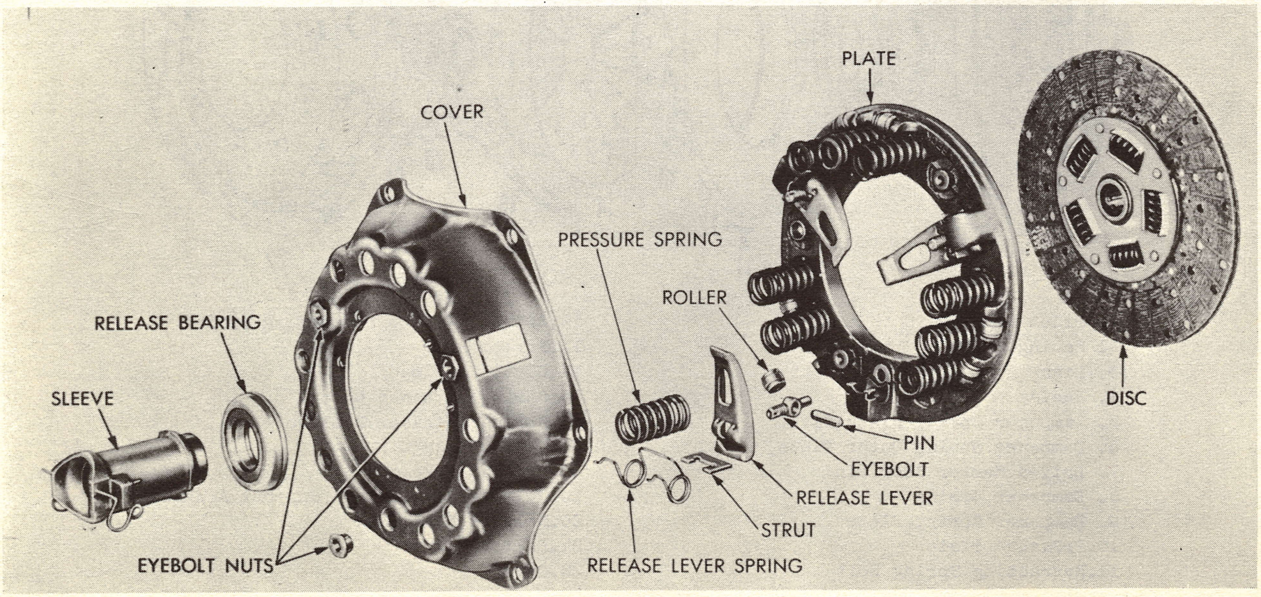


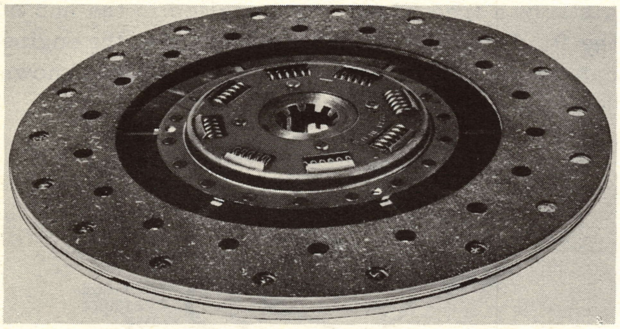
PLATE
COVER
PRESSURE SPRING
ROLLER
RELEASE BEARING
SLEEVE
DISC
PIN
EYEBOLT
RELEASE LEVER
STRUT
EYEBOLT NUTS
RELEASE LEVER SPRING

42-12. Multiple small springs are often placed around the rim of the pressure plate instead of one large spring in the hub.

reduce shock in the drive line, the disc hub is often mounted on springs which permit a limited amount of motion between hub and disc, Fig. 42-13. This construction provides a cushioned engagement and tends to reduce spline wear as well as facing wear.

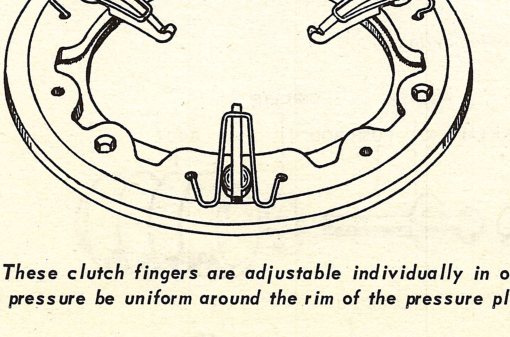
CLUTCH RELEASE LEVERS

To disengage the clutch, the spring pressure must of course be released and the pressure plate allowed to move away from the disc. On the diaphragm or single spring type this is usually accomplished with a lever which contacts a collar or bearing which bears against and compresses the spring. In the multiple spring type it is customary to use three levers or fingers spaced at equal intervals around the clutch, Fig. 42-14.



42-13. The splined hub must fit the splined shaft snugly, yet without any drag or bind. The springs around the hub are to absorb shock when the clutch engages.

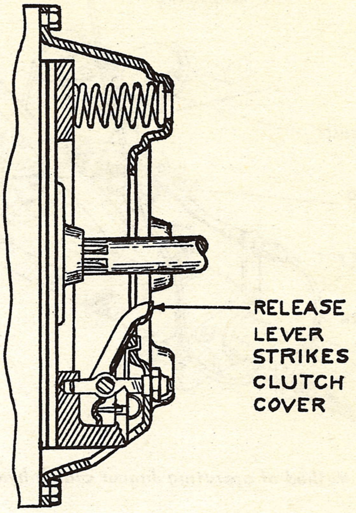
It is of UTMOST IMPORTANCE that these three levers be adjusted properly. Each must have the same clearance and the same amount of movement so that the pressure plate remains parallel with the flywheel at all times. It is also essential to make sure that the levers do not strike the clutch cover in any way that would restrict their free movement. See Fig. 42-15.



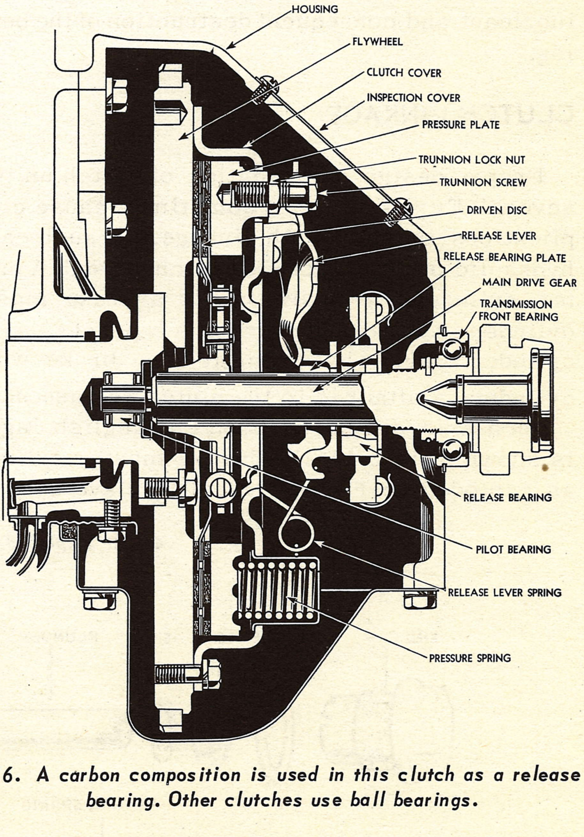
42-14. These clutch fingers are adjustable individually in order that the pressure be uniform around the rim of the pressure plate.

CLUTCH RELEASE BEARINGS

The collar or bearing against which these levers bear is known as a release bearing. In most cases it is a ball bearing but in some models the bearing is made of a composition such as carbon or graphite. A release bearing of this type is shown in Fig. 42-16.

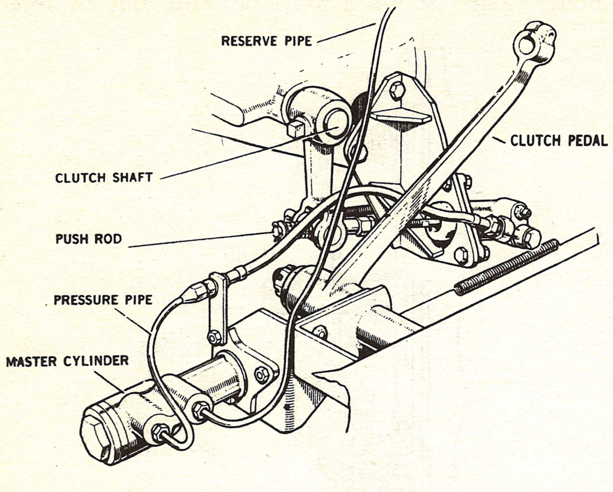

RELEASE LEVER STRIKES CLUTCH COVER

42-15. When the facing on the disc is worn too thin, the end of the release lever may strike the cover.


HOUSING
FLYWHEEL
CLUTCH COVER
INSPECTION COVER
PRESSURE PLATE
TRUNNION LOCK NUT
TRUNNION SCREW
DRIVEN DISC
RELEASE LEVER
RELEASE BEARING PLATE
MAIN DRIVE GEAR
TRANSMISSION FRONT BEARING
RELEASE BEARING
PILOT BEARING
RELEASE LEVER SPRING
PRESSURE SPRING

42-16. A carbon composition is used in this clutch as a release bearing. Other clutches use ball bearings.

Some clutch throw-out bearings require periodic lubrication and others have the lubricant sealed within the bearing at the time of manufacture and require no further attention. Ordinarily these bearings are not liable to cause trouble unless the car driver has the bad habit of "riding" the clutch pedal. If the driver does ride with his foot on the pedal the weight of his foot may depress the pedal enough to cause continuous rotation of the bearing.


RESERVE PIPE
CLUTCH PEDAL
CLUTCH SHAFT
PUSH ROD
PRESSURE PIPE
MASTER CYLINDER

42-17. Method of operating Jaguar clutch hydraulically.

As this bearing rotates at engine speed, the result will be overheating of the bearing, loss of lubricant and consequent destruction of the bearing.

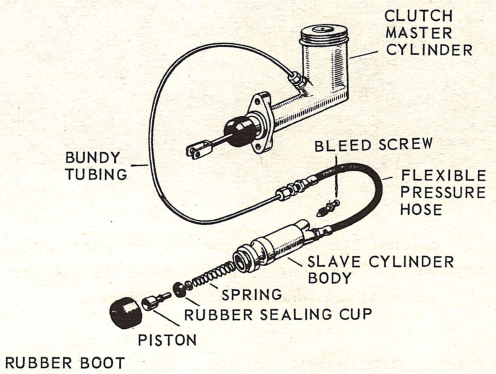
CLUTCH LINKAGE

Frame design and location of clutch units in several European cars sometimes cause complications in the clutch linkage. In such cases hydraulic operation of the clutch is used. A master cylinder, very similar to a brake master cylinder is attached to the clutch pedal. A slave cylinder, somewhat similar to a brake wheel cylinder is attached to the clutch release shaft.

Such a layout as used on the English Jaguar is shown in Fig. 42-17 with the master cylinder as exploded in Fig. 42-18. The slave cylinder mounted on the clutch housing has a bleed valve on it for bleeding air after the system has been opened for any reason. Service on the hydraulic cylinders is the same as for brake cylinders. Another such unit as used on the English Standard is shown in Fig. 42-19 with the slave cylinder as exploded.

AUTOMATIC CLUTCHES

Automatic clutches are described previously herein, but Daimler-Benz in Germany have made some improvements in design in their hydro-automatic clutch. One major improvement consists of a free wheel unit installed in the hub of the fluid flywheel in such manner that the engine can be used in decelerating. The system is known as the Hydrak, and consists of a hydraulic clutch or fluid flywheel connected to a single plate dry clutch as shown in Fig. 42-20. The complete system with the control elements is shown in Fig. 42-21.

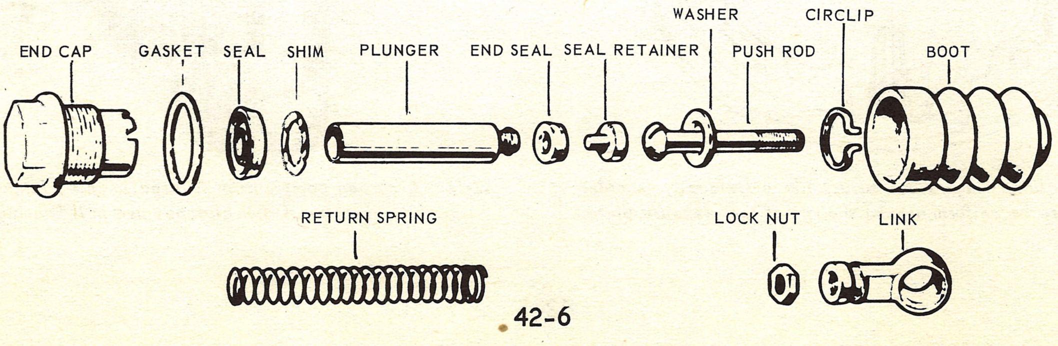

CLUTCH MASTER CYLINDER
BUNDY TUBING
BLEED SCREW
FLEXIBLE PRESSURE HOSE
SLAVE CYLINDER BODY
SPRING
RUBBER SEALING CUP
PISTON
RUBBER BOOT

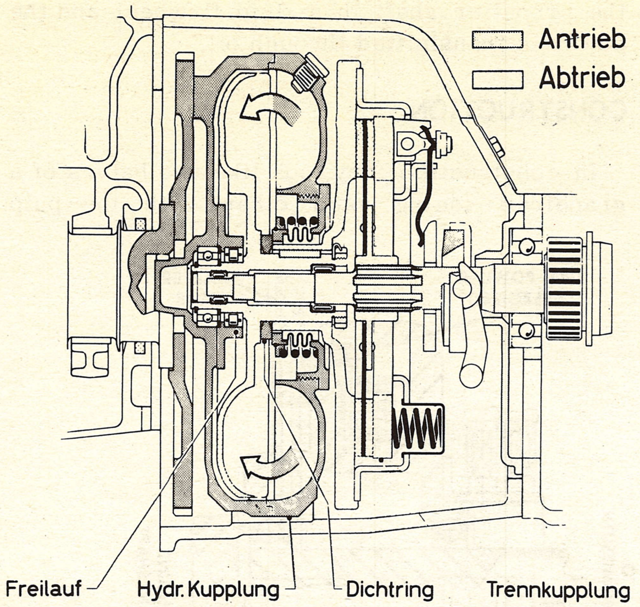
42-19. Master cylinder, slave cylinder and connections used in hydraulic operation of Standard clutch.

The method of operation is as follows: When the gear shift lever is touched, it releases an electric contact which opens a valve of the vacuum operated booster unit. This connects the booster unit with the intake manifold or a vacuum reservoir, as the case may be. The booster or power unit then disengages the plate clutch.

The driving and the driven parts of the hy-

42-18. Exploded view of clutch master cylinder.


END CAP
GASKET
SEAL
SHIM
PLUNGER
END SEAL
SEAL RETAINER
WASHER
PUSH ROD
CIRCLIP
BOOT
RETURN SPRING
LOCK NUT
LINK


Antrieb
Abtrieb
Freilauf
Hydr. Kupplung
Dichtring
Trennkupplung

42-20. Hydrak cross-section. Antrieb–driving members, Abtrieb–driven members, Freilauf–free wheel unit, Hydr. Kupplung–hydraulic clutch (fluid flywheel), Dichtring–gasket, Trennkupplung–mechanical clutch.

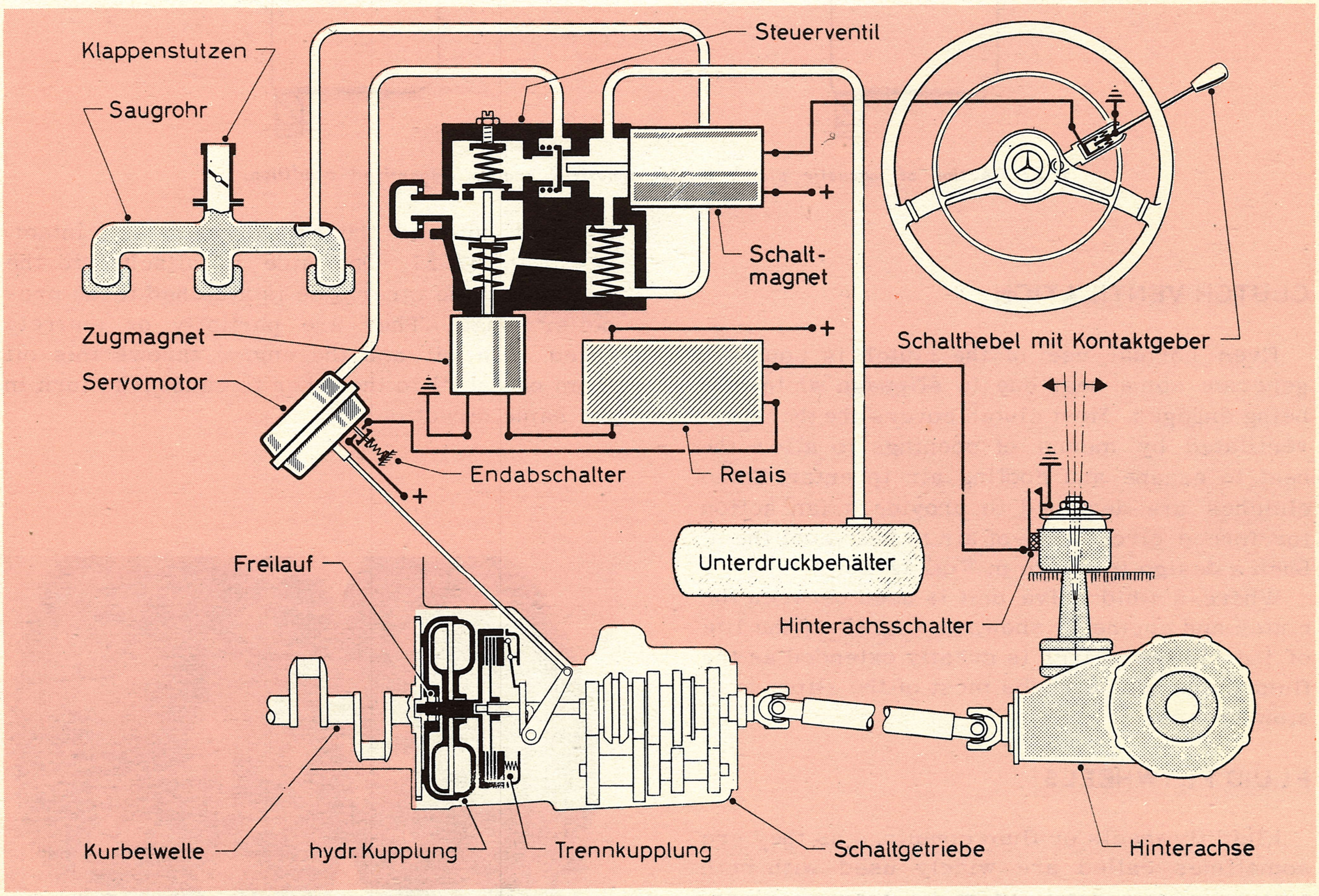
draulic clutch are bridged over by a free-wheel unit which gets into action when the speed of the rear wheels is higher than the speed of the engine. A special control device governs the engaging of the mechanical clutch depending on whether the rear axle is in traction or being pushed by car momentum.

MAGNETIC CLUTCHES

Another type of clutch is known as the magnetic type. It is used on air conditioning compressors, fans, etc. and as a unit to replace clutch and transmission.

The structure comprises a coil completely enclosed by a magnetic circuit, and a mixture of magnetizable metal and dry lubricant is used as the clutching medium.

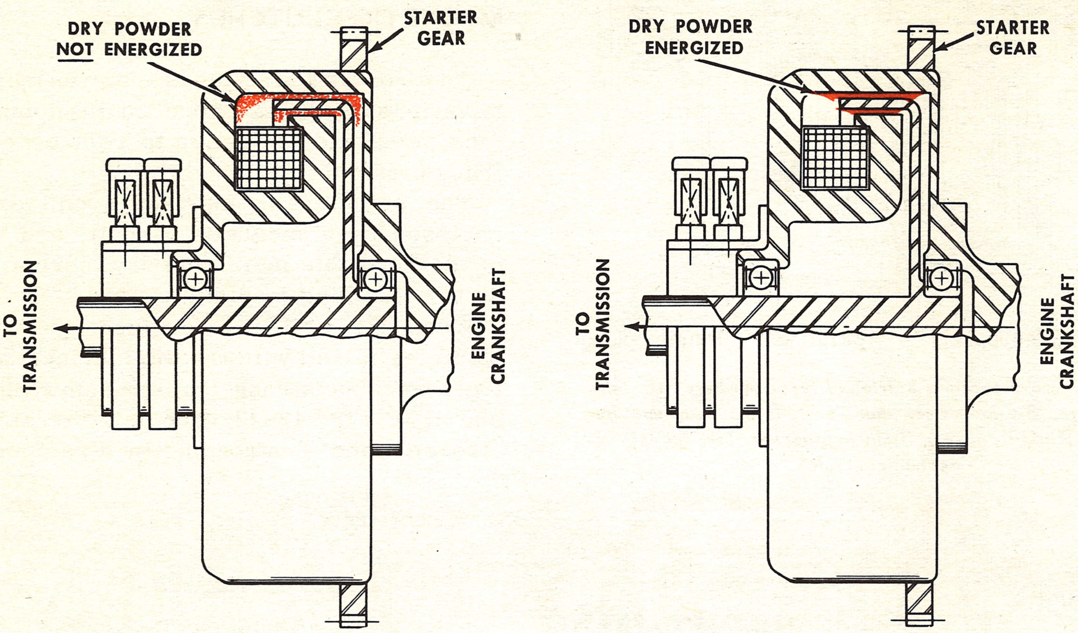
When the coil is energized, the fine metal particles mixed with the dry lubricant are drawn together in a strong load-transmitting bond as shown in Fig. 42-22. The mixture is literally "frozen" and "unfrozen" in direct proportion


Klappenstutzen
Saugrohr
Steuerventil
Schalt-magnet
+
+
Zugmagnet
Servomotor
Schalthebel mit Kontaktgeber
Endabschalter
+
Relais
Unterdruckbehälter
Freilauf
Hinterachsschalter
Kurbelwelle
hydr. Kupplung
Trennkupplung
Schaltgetriebe
Hinterachse

42-21. Hydrak installation. Klappenstutzen – throttle housing, Saugrohr – intake manifold, Steuerventil – control valve, Schaltmagnet – solenoid magnet (actuating), Zugmagnet – solenoid magnet (tenstio), Servomotor – vacuum booster, Schalthebel mit Kontaktgeber – contact points, Endobschalter – limit switch, Relais – relay, Freilauf – free wheel unit, Unterdruckbehalter – vacuum reservoir, Hinterachsschalter – governor, Kurbelwelle – engine crankshaft, Hydr. Kupplung – hydraulic clutch (fluid flywheel), Trennkupplung – mechanical clutch, Schaltgetriebe – transmission, Hinterachse – rear axle.

to the amount of current applied. Therefore, any desired amount of slippage or a solid drive may be had.

When applied as a main drive, the clutch is as shown in Fig. 42-23. Used as a complete clutch and transmission assembly, the power flow is shown diagrammatically in Fig. 42-24.



42-22. Action of magnetic clutch in de-magnetized and in magnetized condition.

CLUTCH VENTILATION

Even normal use of the clutch is bound to generate some heat due to slippage while it is being engaged. Most clutch covers are therefore ventilated by means of openings to allow the heat to escape and cooling air to enter. Some clutches are designed to provide a fan action for forced circulation of air to help cool them. Such a design is shown in Fig. 42-25.

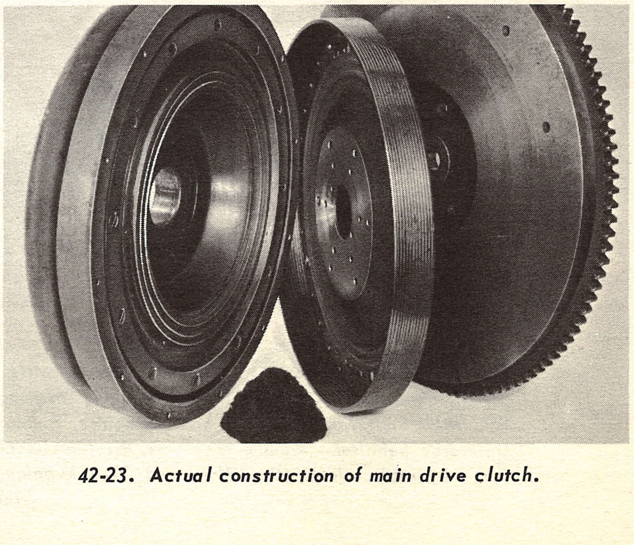
Where a fluid drive unit is used between the clutch and engine as shown in Fig. 42-26 the life of the clutch facings is greatly extended as the fluid drive unit absorbs most of the slippage at slow speeds.

FLUID FLYWHEELS

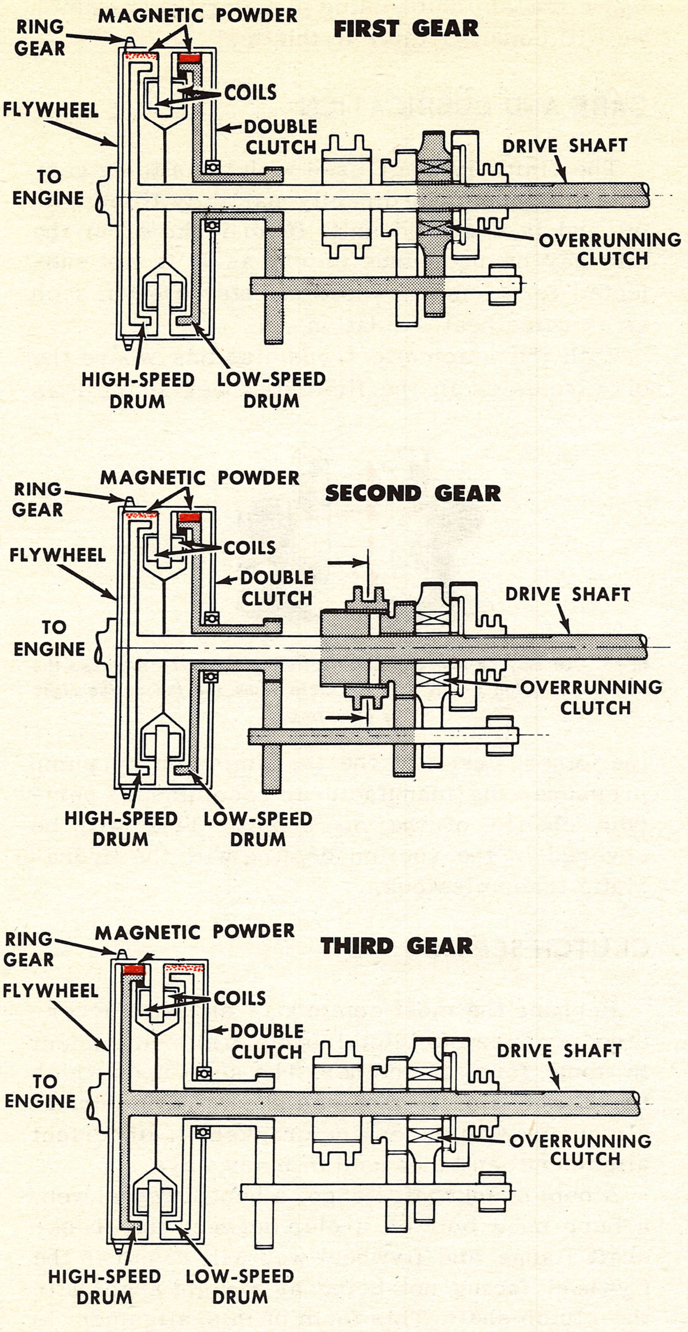
Fluid flywheels or fluid couplings as they are sometimes called are widely used with both automatic and semi-automatic transmissions. They act as a sort of automatic clutch as they slip at idling speed and hold to transmit power as the engine speed increases. There is no mechanical connection between the engine and *the propeller shaft in a fluid flywheel and the* power is transmitted through oil.

CONSTRUCTION

In construction they look like two halves of a grapefruit facing each other with the pulp scooped out and the cell dividers left intact. See Fig. 42-27. One side is attached to the engine and the other side is attached to the propeller shaft. They are partially or entirely filled with oil and the engine throws this oil from one shell to the other to cause it to turn in the same direction.



42-23. Actual construction of main drive clutch.


FIRST GEAR
RING GEAR
MAGNETIC POWDER
COILS
FLYWHEEL
DOUBLE CLUTCH
DRIVE SHAFT
TO ENGINE
OVERRUNNING CLUTCH
HIGH-SPEED DRUM
LOW-SPEED DRUM
SECOND GEAR
RING GEAR
MAGNETIC POWDER
COILS
FLYWHEEL
DOUBLE CLUTCH
DRIVE SHAFT
TO ENGINE
OVERRUNNING CLUTCH
HIGH-SPEED DRUM
LOW-SPEED DRUM
THIRD GEAR
RING GEAR
MAGNETIC POWDER
FLYWHEEL
COILS
DOUBLE CLUTCH
DRIVE SHAFT
TO ENGINE
OVERRUNNING CLUTCH
HIGH-SPEED DRUM
LOW-SPEED DRUM

42-24. One method of arranging a pair of magnetic clutches to obtain a complete automatic transmission.

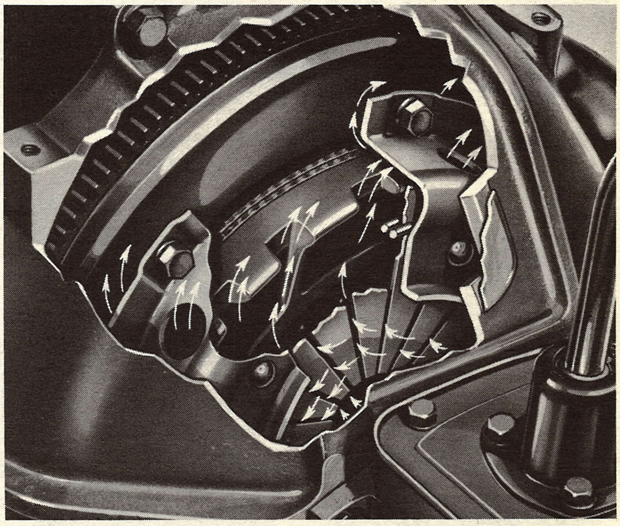
OPERATION

The principle of operation can be best understood by placing two electric fans facing one another. If one fan is then operated the air blast will cause the other fan to rotate. See Fig. 42-28. In this illustration the fan connected to the outlet would represent the engine half of the fluid flywheel known as the impeller. The other fan which is not connected to the electricity would be the runner and would be connected to the propeller shaft.

It might be possible to compare the action of a fluid flywheel with a man wading in deep water. If the man walks slowly there is little resistance to his motion from the water. If however he tries to walk fast, he immediately finds terrific resistance to his progress. In the same way the fluid flywheel transmits little power at slow speed but the instant the impeller is speeded up it forces the fluid---in this case oil instead of water---against the vanes of the runner with ever increasing force.

FLUID FLYWHEEL NOT A TORQUE CONVERTER

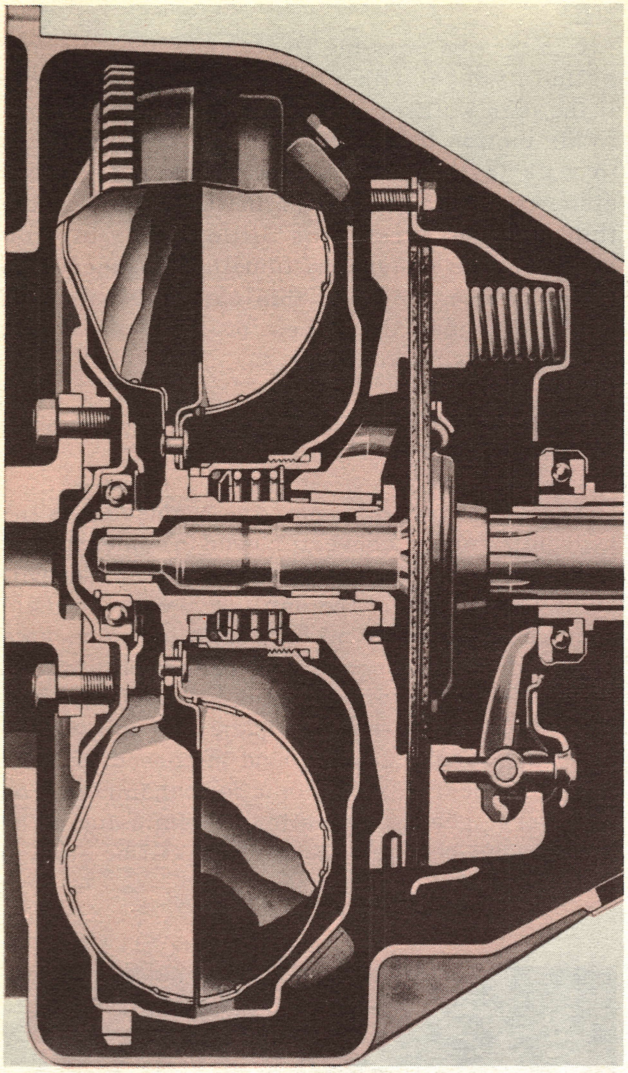
The fluid flywheel is not to be confused with the hydraulic torque converter used in some types of fully automatic transmissions which we will study later. Both of the units have vanes in them and are operated by oil but the fluid flywheel we are now considering cannot increase or diminish torque. (Fluid flywheels can be so constructed that they will increase torque). The unit we are now studying is usually found in connection with a sliding gear semi-automatic transmission or planetary gear automatic transmission. The differences between these units will be studied later herein.



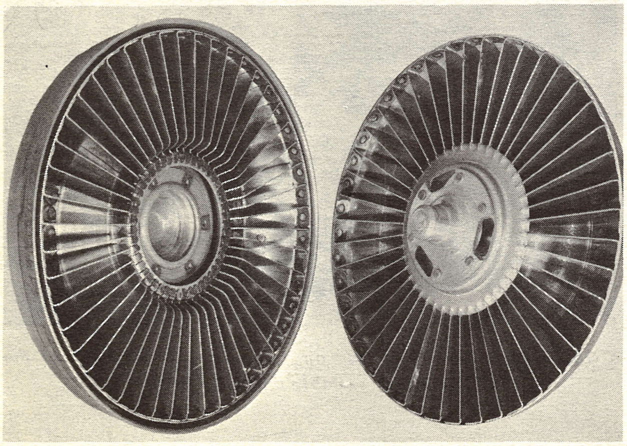
42-25. Circulation of cooling air is provided by rotation of the clutch with suitably designed cover.

NEED FOR A CLUTCH

As sliding gear transmissions are shifted at varying speeds it is desirable to have a clutch to facilitate shifting gears when the coupling is transmitting power at higher than idling speed.



42-26. Where a fluid flywheel is used in connection with a clutch, there is little slippage of the clutch disc.



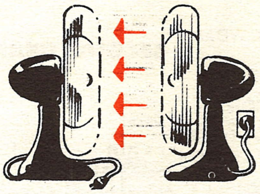
42-27. The two halves of a fluid flywheel resemble a huge grapefruit with the pulp scooped out between the divisions.

This clutch is interposed between the fluid flywheel and transmission as shown in Fig. 42-29. This clutch is not necessary in the fully automatic transmission using planetary gears which we will consider later in this text.

CARE AND LUBRICATION

The fluid flywheel used with the sliding gear transmission is ordinarily partially filled with oil and is a sealed unit. If no leaks occur the oil may be used indefinitely as it is not subjected to the usual causes of deterioration such as extreme heat, oxidation, etc.

With the automatic transmissions where the oil circulates in the fluid flywheel as well as the other parts of the transmission by pump pressure, the manufacturer recommends periodic change of the oil supply. This will be covered in the section dealing with the Hydra-Matic transmissions.

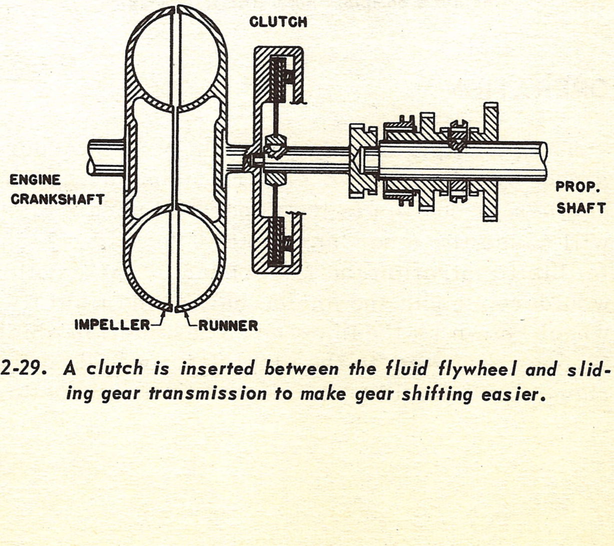


42-28. Air may be considered as a fluid and serves to cause the disconnected fan at the left to rotate when the fan at the right is operating.

CLUTCH SERVICE

Perhaps the most common - and least understood - cause of clutch trouble is mis-alignment in some form or another. The shaft upon which the clutch disc is mounted should be in perfect alignment with the engine crankshaft. Imperfect alignment can be caused in many ways.

A bent crankshaft flange, a bent flywheel web, a burr on a bolt or a chip between the crankshaft flange and flywheel web will result in the flywheel facing not being at a right angle with the clutch shaft. This form of mis-alignment is



42-29. A clutch is inserted between the fluid flywheel and sliding gear transmission to make gear shifting easier.

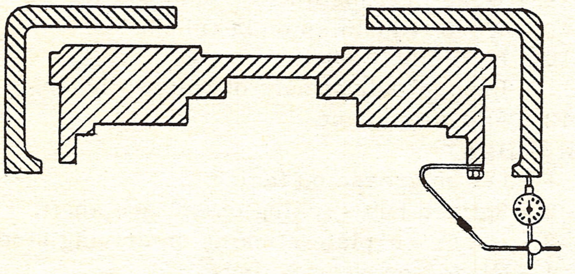
checked as shown in Fig. 42-3.

Another form of mis-alignment can be caused by a warped clutch housing. This condition can be checked by mounting a dial gauge as shown in Fig. 42-30.

A warped transmission housing, an incorrectly centered transmission housing or chips between the clutch housing and transmission housing will have the same effect.

In addition to mis-alignment of the housings there is always a possibility of mis-alignment of the clutch shaft. A worn front bearing in the transmission or excess wear in the pilot bearing at the front end of the shaft will permit the clutch shaft to run untrue. Another frequent cause of mis-alignment is a sprung clutch shaft.

A bent or sprung clutch shaft or clutch disc is usually caused by carelessness in removing or replacing the transmission. If the transmission is unsupported while being removed or installed, the weight of the unit is liable to spring the shaft or disc. For this reason a transmission lift or hoist should always be used so that the unit can be supported in alignment while it is being moved into or out of place.



42-30. Method of using a dial gauge to check for a warped clutch housing.

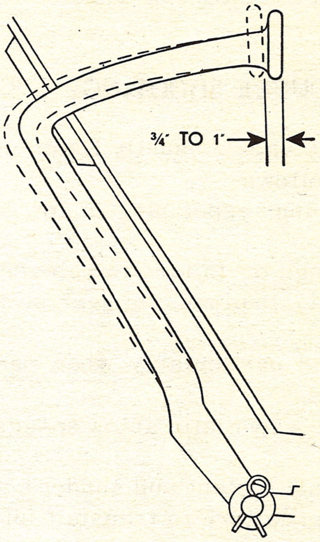
Distortion of the clutch cover will also cause mis-alignment. Such distortion or warpage is often caused by carelessness in removing or replacing the cover. If the retaining bolts are loosened or tightened unevenly, the cover is liable to be sprung or distorted by the spring pressure.

The safest method is to insert wood or fiber blocks in the form of wedges between the release levers and the cover before the bolts are loosened. These blocks keep the spring tension off the bolts and facilitate removal and replacement of the bolts. After reinstallation, the wedges must of course be removed.

Another thing to be kept in mind is that the engine is usually balanced with the clutch assembly installed. Therefore before removing the clutch cover, it should be marked and replaced in the same relative position. Otherwise the rotating balance of the engine assembly may be disturbed thus creating vibration.

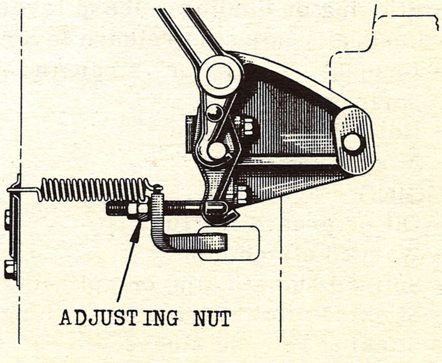
CLUTCH ADJUSTMENT

The principal cause of damaged clutch release bearings is neglect of clutch adjustment to compensate for wear. As the lining is gradually worn from the disc in normal use the pressure plate will approach the flywheel and the pedal will consequently be forced backward by the throw-out bearing. If the pedal is thus forced into contact with the toe boards the bearing will be turning at all times and the result will be the same as riding the clutch.



42-31. Method of measuring for correct pedal clearance.

Therefore the pedal clearance should be checked occasionally and the clutch adjusted if necessary to restore the proper clearance. This proper clearance is usually specified by the car manufacturer as about one inch between pedal and toe board. See Fig. 42-31. In some cases this adjustment must be made within the clutch by means of adjusting screws or shims.



42-32. One method of adjusting pedal for correct clearance.

In other cases the necessary adjustment is made at the clutch pedal shaft in a manner similar to the adjustment shown in Fig. 42-32.

It will be obvious that continuous pressure on the clutch throw-out bearing will also tend to partially disengage the clutch and thus cause the clutch to slip. In addition to ruining the throw-out bearing the clutch disc friction facing will overheat and wear rapidly. A slipping clutch will generate a great amount of heat.

CLUTCH TROUBLE SHOOTING

Clutch troubles are usually listed under eight headings as follows:

A - Chattering: especially in low or reverse gear.
B - Dragging: or failure to release promptly and fully thus making gear shifting difficult.
C - Squeaks; particularly when pedal is depressed.
D - Rattles: especially at low speeds or standing.
E - Grabbing: violent and sudden engagement.
F - Slipping: failure to transmit full power.
G - Failure to transmit power at all.
H - Vibration at either high or low speed or periodically.

CHATTERING

1 - Oil or grease on facing.
2 - Glazed or worn facing.
3 - Worn, loose or spongy engine mountings.
4 - Worn or loose splines in clutch hub or on clutch shaft.
5 - Wear or looseness in universal joint, differential, drive axles, torque tube or torque rod mountings.
6 - Splined hub sticking on splined shaft.
7 - Cracked or scored pressure plate or flywheel face.
8 - Warped clutch disc.
9 - Warped pressure plate.
10 - Pressure plate sticking on driving studs.
11 - Sticking or binding release levers.
12 - Unequally adjusted release levers.
13 - Unequal length or strength of clutch springs.
14 - Bent clutch shaft.
15 - Mis-alignment.

DRAGGING

1 - Oil or grease in clutch.
2 - Warped clutch disc.
3 - Splined hub sticking on splined shaft.
4 - Sticking pilot bearing or bushing.
5 - Sticking release sleeve.
6 - Warped pressure plate or clutch cover.
7 - Broken disc facing.
8 - Accumulation of dust in clutch.
9 - Incorrect clutch or pedal adjustment.
10 - Engine idling too fast.
11 - Mis-alignment.

SQUEAKS

1 - Clutch release bearing needs lubrication.
2 - Pilot bearing needs lubrication.
3 - Release sleeve needs lubrication.
4 - Mis-alignment.

RATTLES

1 - Loose hub in clutch disc.
2 - Broken or loose anti-rattle springs on plate.
3 - Worn release bearing.
4 - Worn release parts.
5 - Worn pilot bearing.
6 - Worn splines in hub or on shaft.
7 - Worn driving pins in pressure plate.
8 - Wear in transmission or drive line.
9 - Worn transmission bearings.
10 - Bent clutch shaft.
11 - Unequal adjustment of release levers.
12 - Mis-alignment.

GRABBING

1 - Oil or grease on facing.
2 - Splined hub sticking on splined shaft.
3 - Pressure plate sticking on driving studs.
4 - Glazed or worn facings.
5 - Sticking or binding release levers.
6 - Sticking or binding clutch pedal or linkage.
7 - Mis-alignment.

SLIPPING

1 - Worn facings.
2 - Weak or broken springs.
3 - Improper clutch or pedal adjustment.
4 - Oil or grease on facings.
5 - Warped disc.
6 - Warped pressure plate.
7 - Sticking release levers.
8 - Pressure plate sticking or binding on studs.
9 - Mis-alignment.

FAILURE

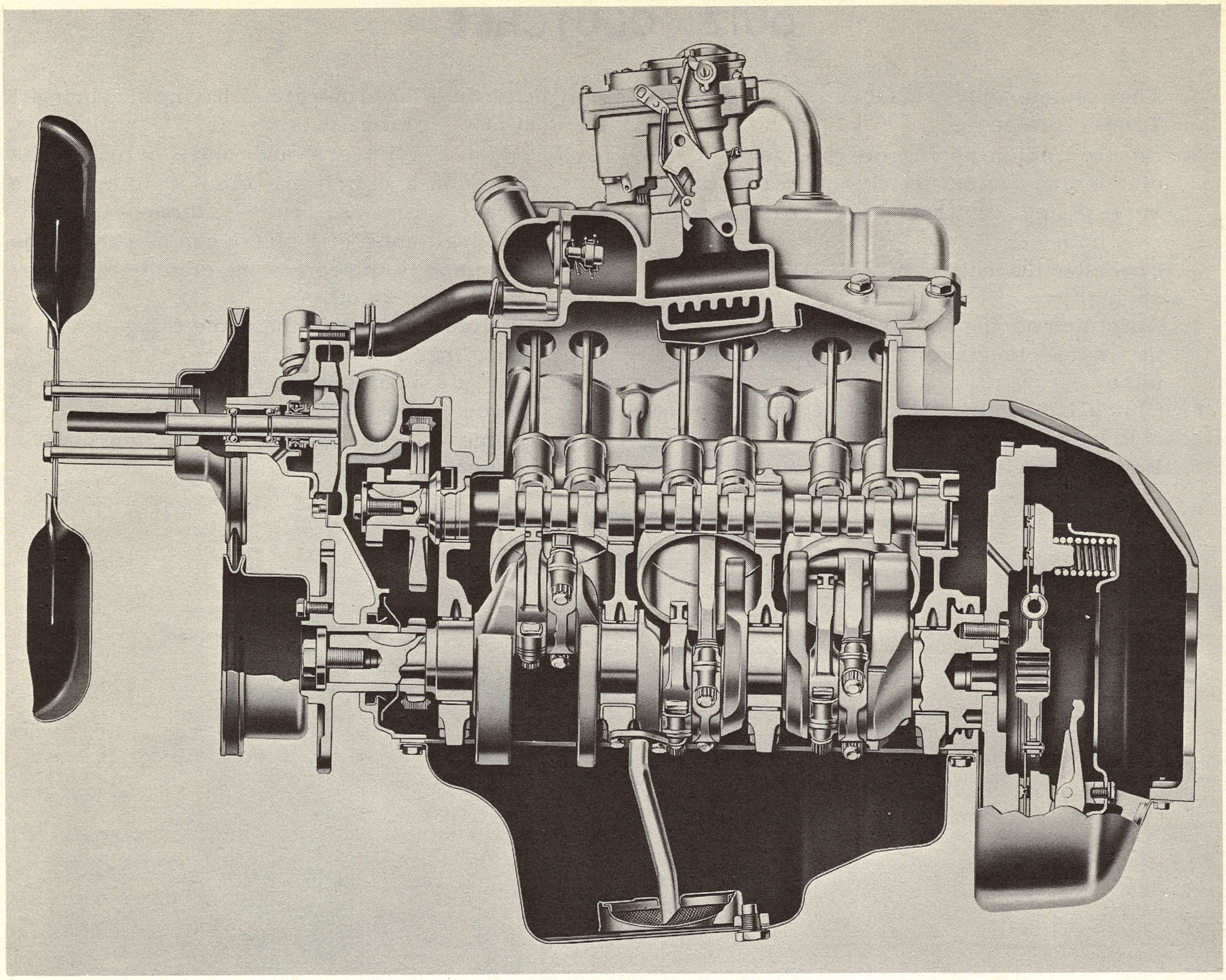
1 - Disc hub torn out.
2 - Friction discs torn off or worn out.
3 - Broken springs.
4 - Incorrect adjustment of pressure plate.
5 - Improper adjustment of clutch or pedal.
6 - Splined hub stuck on splined shaft.

VIBRATION

1 - Bent clutch shaft.
2 - Defective clutch disc.
3 - Dust in clutch.
4 - Improper assembly of clutch to flywheel.
5 - Use of rigid disc instead of flexible type.
6 - Unmatched springs.
7 - Mis-alignment.

QUIZ - CLUTCHES

1. The clutch disc surfaces must be flat. True---, false---.
2. Do the clutch spring or springs hold the clutch disc against the flywheel or the pressure plate? Flywheel---, Pressure plate ---, both---.
3. Describe the action of a diaphragm clutch spring.
4. All clutch springs of any one clutch must be the same length and strength. True---, false---.
5. Clutch hub splines should be loose on the clutch shaft. True---, false---.
6. How many clutch release levers are customarily used on a clutch having six springs? One---, three---, six---.
7. Master cylinders and slave cylinders as used on a clutch are similar to hydraulic brake cylinders. True---, false---.
8. A single magnetic clutch can be used on an automobile to replace the clutch---, transmission---, both---.
9. A fluid flywheel is the same thing as a fluid coupling. True---, false---.
10. A fluid coupling is the same thing as a torque converter. True---, false---.
11. Name six causes for mis-alignment in a clutch.



Section view - Buick Special V-6. Note clutch at the right.

TRANSMISSION FUNDAMENTALS

NEED FOR A TRANSMISSION

Some sort of speed and power changing device is needed between the engine of an automobile and the driving wheels. This is because of the constantly changing requirements placed on the engine and the inherent limitations of a gasoline engine. Such devices are ordinarily called transmissions or gear boxes.

To set an automobile in motion requires much more power than to keep it rolling after it gets under way. Therefore the automobile demands much power when the engine is developing very little. Of course if the engine were of giant size the car could be put in motion with nothing more than a clutch of some sort to obtain gradual application of the load on the engine. Such an engine would of necessity be sinfully wasteful of gasoline.

TORQUE MULTIPLICATION

An automobile could be started on a level road without a transmission as the engine could be speeded up until it develops sufficient power and then the clutch engaged. Such a start would be slow, noisy and uncomfortable in addition to placing a tremendous strain on the engine and driving parts of the automobile. But cars often are required to travel up steep hills or even start on a hill and then they must have some means of multiplying the torque or turning effort of the engine.

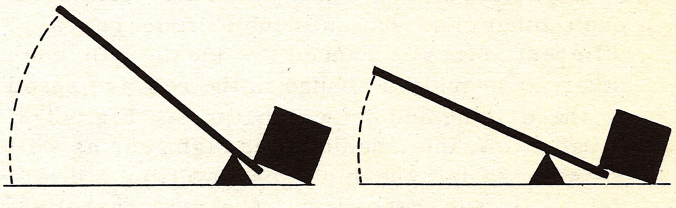
Power and torque are not the same thing. Torque is derived from power but the operating characteristics of a gasoline engine are such that the maximum torque or turning effort is not necessarily attained at the peak of power output. These facts are completely explained in the engine section of this text and make it clear that the amount of torque obtainable from a source of power is proportional to the distance from the center of rotation at which it is applied.

APPLICATION OF TORQUE

It is obvious therefore that if we have a shaft - such as an engine crankshaft - rotating at any given speed we can put gears or pulleys on the shaft of different sizes and obtain different results. If we put a large gear or pulley on the shaft, we will get more speed and less power at the rim than with a small pulley.

Now we can also use another shaft parallel to our driving shaft and place gears or pulleys on it also that mate up with the driving shaft. By altering the sizes of the gears or pulleys on either or both shafts, we can obtain almost any desired combination of speed or power within the limits of the engine's ability. That is exactly what an automobile transmission does by means of gears or some other methods we shall discuss later.

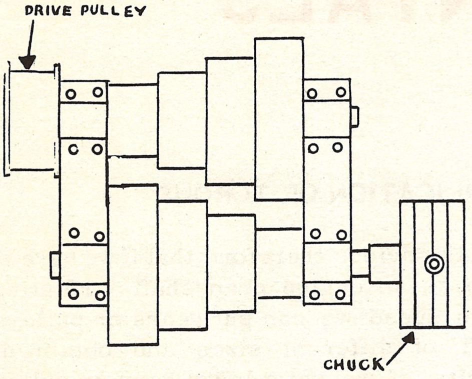
Gears are simply a means of applying leverage to rotating parts. You are familiar with the fact that an ordinary lever has more power as the fulcrum gets closer to the object of power application. The closer the fulcrum approaches the object the longer will be the distance the lever end has to be moved. See Fig. 43-1. The same principle applies to gears and pulleys.



43-1. The distance between the fulcrum and the object is comparable to the distance between the center and rim of a gear or pulley, thus a small gear will drive a large gear more slowly but with greater power.

A good example of this is a machinist's lathe with stepped pulleys for the drive belt. When the machinist wants to make a light cut he gets speed by putting the belt on the end of the drive shaft having the larger pulley with the corresponding small pulley on the lathe spindle shaft. If he needs more power for a heavier cut, he trades speed for power and puts the belt at the other end. See Fig. 43-2.

With a gasoline automobile of modern design we have both speed and power in plentiful measure available to the driver by means of the gearing in the transmission. The engineer who designed it selected the gear sizes that would give the best all around performance. In selecting the gears the engineer had a choice between speed and power. He could sacrifice some power and get more speed---or he could do with less speed and have more power. The final choice of gearing is a compromise to provide enough of each to suit the needs and desires of the car owner.



43-2. Stepped pulleys on parallel shafts provide a means of trading speed for power or vice-versa by shifting the belt from one set of pulleys to another. Gears may be used instead of pulleys.

TRANSMISSION DEVELOPMENT

A Frenchman named Levassor is generally credited with the first sliding gear transmission. It consisted of two shafts mounted parallel to each other and had slideable spur gears of different sizes arranged to mesh with each other to provide a change in the relative speed of the driving and driven shafts. See Fig. 43-3. It had a low, intermediate and high gear as well as reverse but the high gear was not a direct drive. It was geared up. The modern helical gear, synchro-mesh, roller bearing transmission is indeed far removed from the plain bearing, spur gear contraption which was the granddaddy of all transmissions.

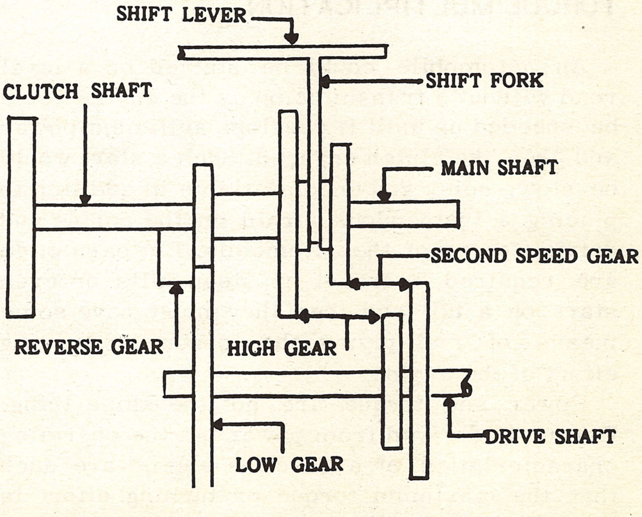
GEAR RATIOS

A certain amount of gear noise was expected and accepted as inevitable in cars for many years. This was especially true of geared up overdrives which were expected to hum or whine. They did. Of course less noise was encountered in direct drive as fewer gears were in operation. Changes in gear cases, gear design and gear ratio* have all contributed to quieter operation. Gear ratios in transmissions are not standardized, but are changed around from time to time to fit changes in the engine, car weight, etc. in order to obtain maximum performance of the car.

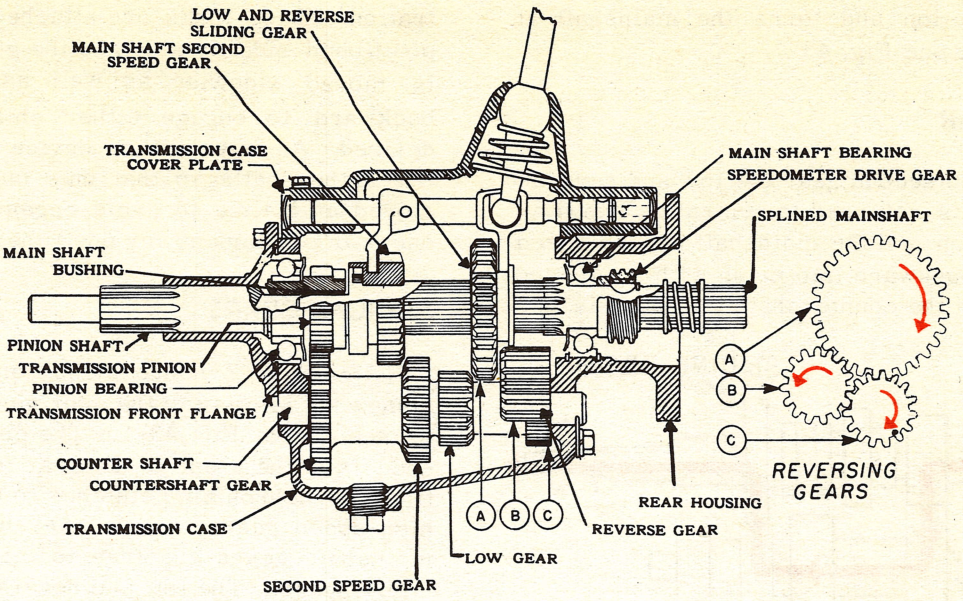
A typical automobile sliding gear transmission has ratios as follows:

Reverse gear	3.5 to 1
Low gear	2.6 to 1
Second gear	1.6 to 1
High gear	1.0 to 1
Overdrive	0.7 to 1

*Gear ratios can be determined by counting the teeth on a pair of gears. If the driving gear has 20 teeth and the driven gears 40 teeth, the ratio would be 2 to 1. If the driving gear had 40 teeth and the driven gear 20 teeth the ratio would be 1 to 2. The transmission gear ratios should not be confused with the final drive ratio or car gear ratio which refers to the overall ratio between the engine revolutions and the rear axle shaft revolutions. This of course includes the gear reduction in the rear axle or differential.



43-3. Here we have a small gear on the mainshaft meshed with a large low gear for maximum power. The second speed pair of gears are nearer the same size for more speed on the drive shaft. In this case the high speed gear on the mainshaft is larger than the high gear on the drive shaft, so the result would be higher speed on the driven shaft than on the driving shaft or an overdrive in high.


LOW AND REVERSE SLIDING GEAR
MAIN SHAFT SECOND SPEED GEAR
TRANSMISSION CASE COVER PLATE
MAIN SHAFT BUSHING
PINION SHAFT
TRANSMISSION PINION
PINION BEARING
TRANSMISSION FRONT FLANGE
COUNTER SHAFT
COUNTERSHAFT GEAR
TRANSMISSION CASE
A
B
C
LOW GEAR
SECOND SPEED GEAR
REVERSE GEAR
REAR HOUSING
MAIN SHAFT BEARING
SPEEDOMETER DRIVE GEAR
SPLINED MAINSHAFT
A
B
C
REVERSING GEARS

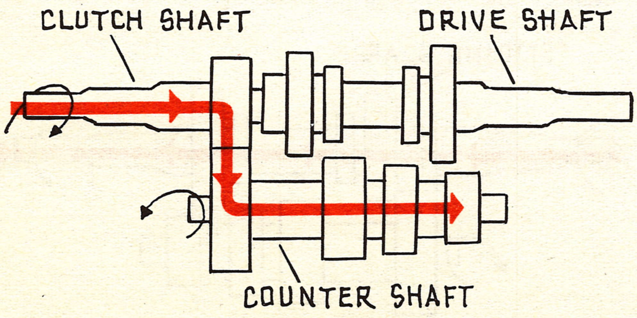
43-4. Conventional spur gear three speed transmission.

In high gear or 1 to 1, the propeller shaft of the car turns at the same speed as the engine crankshaft.

A simple type of conventional three speed spur gear automobile transmission is shown as it would appear with the housing split in two on a vertical plane, in Fig. 43-4. The parts are named and the reverse gearing as seen from the end is shown at the right with the gears identified by A, B and C. The clutch attaches to the pinion shaft at the left, and the propeller shaft attaches to the splined mainshaft at the right. The forward end of the mainshaft runs in the mainshaft bushing within the pinion gear. As shown, the transmission is in the neutral position.

NEUTRAL POSITION

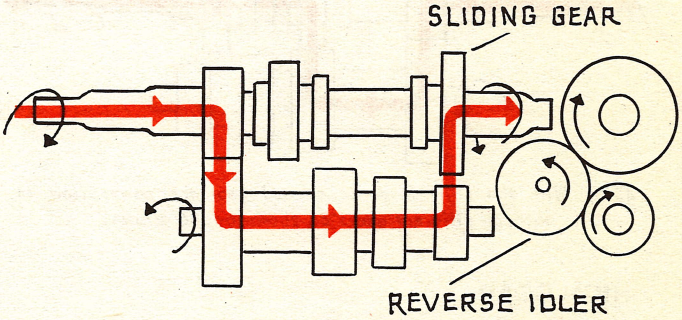
In the neutral position, the clutch turns the pinion shaft which rotates the countershaft gear, the second speed gear, the low gear and the reverse gear, but the mainshaft does not revolve. Also see Fig. 43-5.


CLUTCH SHAFT
DRIVE SHAFT
COUNTER SHAFT

43-5. Three speed transmission in neutral position with engine running. The countershaft turns but no power is applied to the drive shaft.

REVERSE GEAR

In order to engage reverse gear, the low and reverse sliding gear A on the mainshaft is slid backward to engage with the reverse gear B which is driven by gear C on the countershaft. Interposing the idler gear B between gears A and C reverses the rotation of the mainshaft as may be seen from the diagram at the right. Also see Fig. 43-6.


SLIDING GEAR
REVERSE IDLER

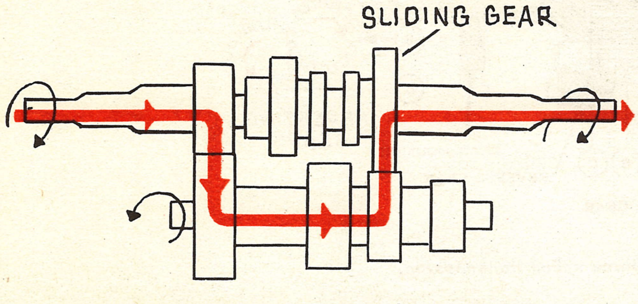
43-6. When the shift lever is moved to reverse, an extra gear is interposed between the mainshaft and countershaft in order to reverse the direction of rotation of the propeller shaft as illustrated.

LOW GEAR

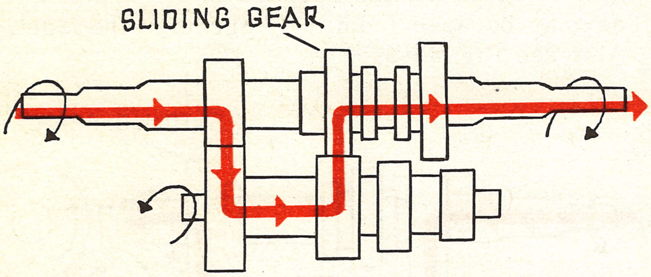
To engage low gear, the low and reverse sliding gear on the mainshaft is slid forward into mesh with the low gear. Thus the pinion shaft turns the countershaft gear which is attached to the low gear which turns the low and reverse gear and the mainshaft thus rotates. The low gear on the countershaft being smaller than the mating gear on the mainshaft provides a gear reduction and turns the mainshaft at slower speed. See Fig. 43-7.

SECOND GEAR

To shift into second gear the low and reverse sliding gear is returned to neutral as shown in the illustration and the mainshaft second speed gear is slid backward into mesh with the second speed gear on the countershaft. As there is less difference in the size of this pair of gears the mainshaft will turn at a higher rate of speed than it did in low gear. The principal gear reduction is now between the pinion shaft gear and the countershaft gear. Refer to Fig. 43-8.



43-7. When the shift lever is placed in low gear, power is transmitted through the gears and shafts as shown by the arrows.



43-8. With the shift lever in second gear the power flow is through different gears as shown by the arrows.

HIGH GEAR

For high gear the mainshaft second speed gear is slid out of engagement with the second speed gear on the countershaft and forward until projections on the rear face of the pinion shaft gear engage with matching indentations or notches in the forward face of the mainshaft second speed gear. The pinion shaft and the mainshaft are now locked together and turn at the same speed or 1 to 1. The gears on the countershaft continue to rotate but do not carry any power as they are not now coupled to any gears on the mainshaft. Also see Fig. 43-9.

The gears are shifted endwise on the mainshaft by collars or forks as shown in the illustration. These forks are attached to two shafts positioned side by side and the gear shift lever is moved sidewise as well as forward and backward to engage either shifting shaft as desired. An interlocking device is placed between the shafts so that only one shaft can be moved at a time to avoid engaging more than one pair of gears at any one time.

HELICAL GEARS

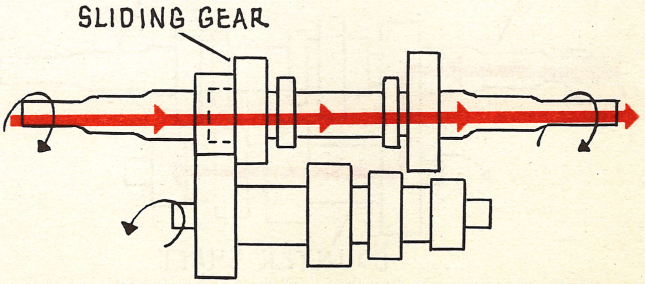
Helical gear synchro-mesh transmissions are somewhat similar to the spur gear type as may be seen from Fig. 43-10. The principal difference is in the shape of the gear teeth, the addition of synchronizing clutches to the second and high speed gears and the fact that some of the mainshaft gears are free to turn on bearings until engaged. The low and reverse sliding gear does not ordinarily need a synchronizing clutch as the car is usually standing still when either of them is shifted into engagement.

It is worthy of note however that some makers - notably Volkswagen - have added synchronizing to low gear.

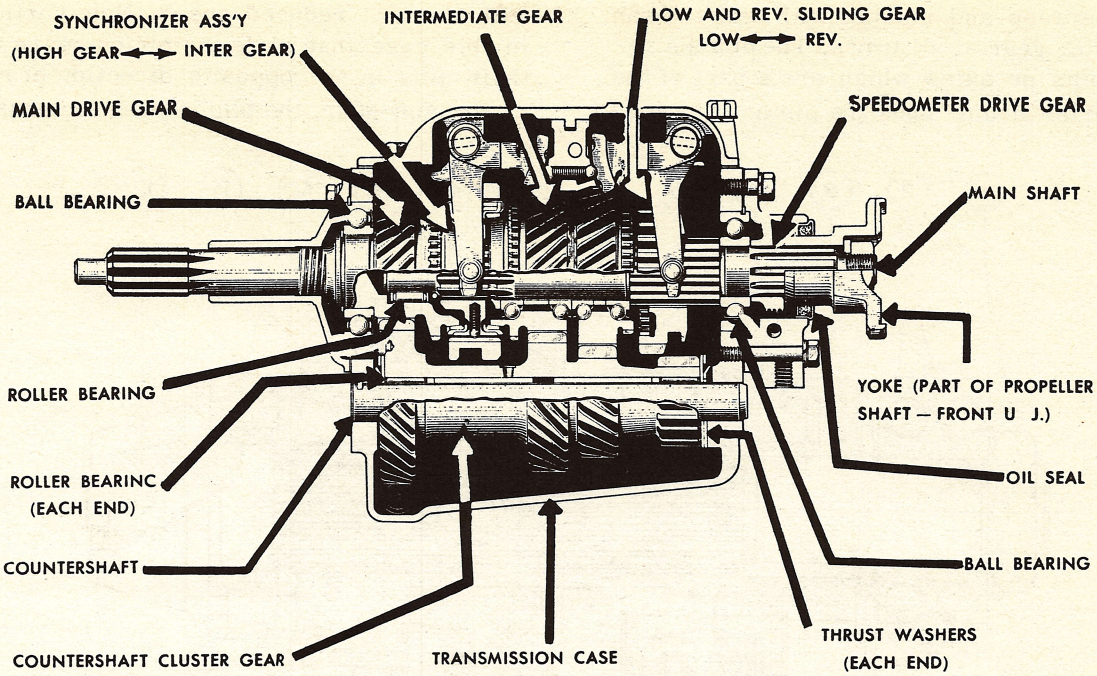
SYNCHRONIZING CLUTCH

The synchronizing clutch is a drum or sleeve that slides endwise on the splined mainshaft by means of the shifting fork. It has a bronze cone on each side that engages with a tapered mating cone on the second and high speed gears. When this drum is moved along the mainshaft the cones act as a clutch and upon touching the gear which is to be engaged the mainshaft is speeded up or slowed down as required until the speeds of the mainshaft and gear are the same.

This action occurred with a partial movement of the shift lever. Completion of the shift lever movement then slides the drum and gear into complete engagement. This action can be readily grasped by remembering that the hub of the drum slides on the splines of the mainshaft to engage the cones and then the drum slides on



43-9. In the high gear position the power does not go through the gears, but directly from the clutch shaft to the propeller shaft as shown by the arrows.


SYNCHRONIZER ASS'Y
(HIGH GEAR ⟷ INTER GEAR)
INTERMEDIATE GEAR
LOW AND REV. SLIDING GEAR
LOW ⟷ REV.
MAIN DRIVE GEAR
SPEEDOMETER DRIVE GEAR
BALL BEARING
MAIN SHAFT
ROLLER BEARING
YOKE (PART OF PROPELLER SHAFT – FRONT U J.)
ROLLER BEARINC (EACH END)
OIL SEAL
COUNTERSHAFT
BALL BEARING
THRUST WASHERS (EACH END)
COUNTERSHAFT CLUSTER GEAR
TRANSMISSION CASE

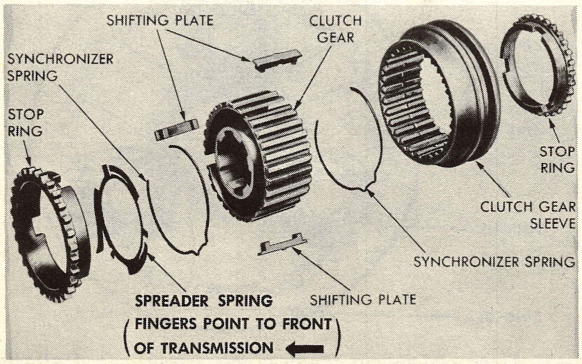
43-10. Cut-away view of typical helical gear synchro-mesh three speed transmission.

the hub to engage the gears. This construction is shown in Fig. 43-11. Fig. 43-12 shows the synchronizer and all other parts in their proper relation.

It may be useful at this time to review the flow of power through the transmission in different gear positions as shown in Figs. 43-5 to 43-9 inclusive.

PLANETARY GEAR SYSTEMS

Planetary gears are simple in design, but their operation is not always well understood. As they are used in one form or another to a great extent in automatic transmissions and overdrives, it is important to understand them thoroughly before any attempt is made to understand the operation of the more complicated units of which they are an important part.


SHIFTING PLATE
CLUTCH GEAR
SYNCHRONIZER SPRING
STOP RING
STOP RING
CLUTCH GEAR SLEEVE
SYNCHRONIZER SPRING
SPREADER SPRING
SHIFTING PLATE
(FINGERS POINT TO FRONT OF TRANSMISSION ⟵)

43-11. Exploded view of this synchronizer assembly indicates proper location of all parts.

BASIC CONSTRUCTION

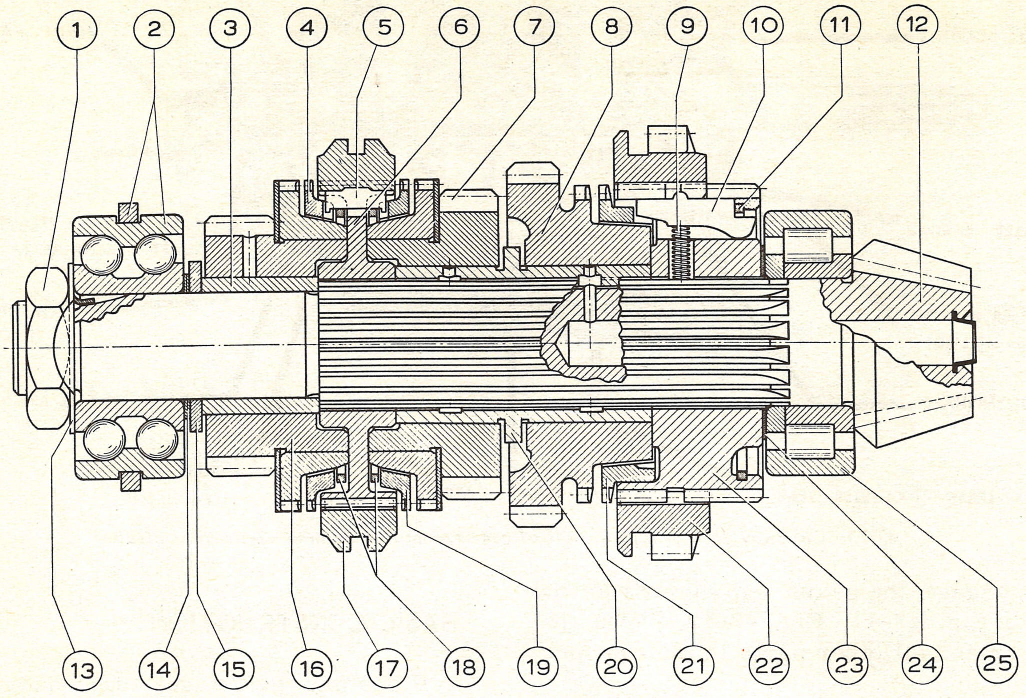
Planetary gears get their name from their similarity to our solar system. The pinions or planet gears each turn on their own axis while rotating at the same time around the central or sun gear in a manner similar to the earth and other planets rotating around the sun. These gears are surrounded by a ring gear as shown in Fig. 43-13.

USED IN DIFFERENT WAYS

Planetary gears are used in one form as a reduction gear and in another form as an overgear. They are used for reverse and are used in multiple sets where more than two forward speeds are wanted. At one time they were operated by levers or pedals. Now they are often controlled by means of hydraulic pressure in combination with automatic mechanical governors, electrical solenoids and vacuum diaphragms.

In a planetary gear set, the gears are in mesh at all times and are never shifted into and out of engagement. The gears are attached to different drums which are in turn attached to the other operating parts of the system. This enables the gears to function in different ways as the various drums are held from rotation by brake bands as will now be explained.

The simple form of planetary gear set shown in Fig. 43-13 has three pinions which are mounted between and meshed with both the sun gear and ring gear at all times. The pinions revolve on pins or axles which are a part of the planet carrier drum. Thus the pinions are held in spaced relation with one another yet can turn freely on their own pins and also rotate around the sun gear and within the ring gear which is also a drum.



43-12. Volkswagen transmission gear Synchronizers. 4. Synchronizer stop ring, 5. Shifting plate, 6. Clutch gear, 7. Third gear, 8. Second gear, 9. Shifting plate spring, 10. Shifting plate.

Therefore we have three units:

1 - The sun gear.
2 - The planet carrier, drum and pinions.
3 - The ring gear and drum.

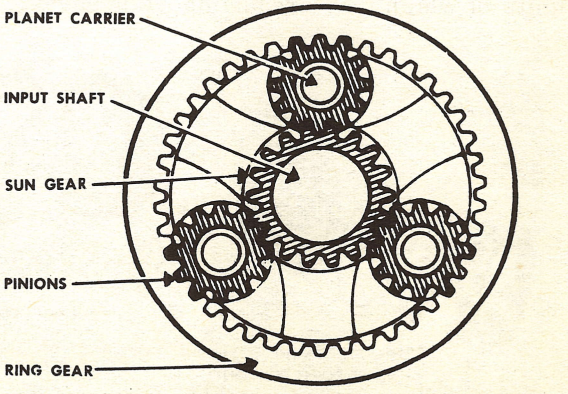
The gears can be arranged so that they will function as driving elements or driven elements. Thus different results can be obtained from these same three units by connecting them in different ways.

METHODS OF CONNECTING PARTS

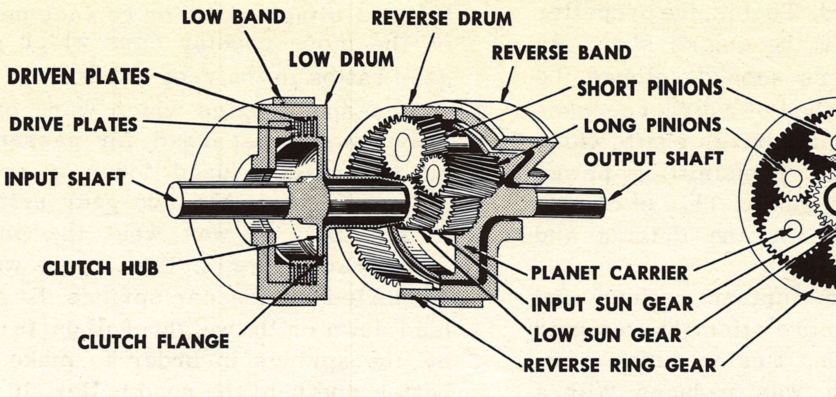
For example, if we connect the engine to the sun gear and the planet or pinion carrier to the propeller shaft the entire assembly will rotate as a unit, the pinions not turning on their pins. In this case there will be no gear reduction and the driven propeller shaft will rotate at the same speed as the driving or engine shaft.

If however we put a brake band around the ring gear and hold it from turning, the pinions will then be forced to travel around inside the ring gear carrying the pinion carrier along with them at reduced speed. Note particularly in this case that while the pinion gears turn on their pins in the opposite direction of rotation of the sun gear, the pinion carrier turns in the same direction as the sun gear but at reduced speed.

It will be obvious that with these few gears and a band to hold the drum that we have a basic transmission of the planetary type with a gear reduction for low gear and a direct drive for high gear. We will need a clutch between the engine and transmission to allow the car to stand still while the engine runs. We will also require some means of reversing the trans-



43-13. Three pinions are shown in this typical set of planetary gears, although two pinions and four pinion types have been used also.

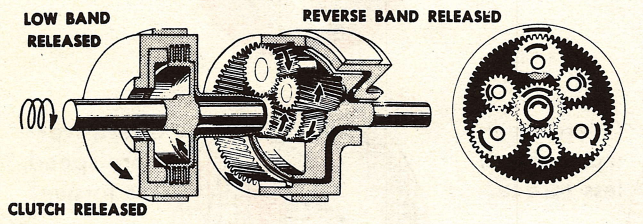

LOW BAND
REVERSE DRUM
LOW DRUM
REVERSE BAND
DRIVEN PLATES
SHORT PINIONS
DRIVE PLATES
LONG PINIONS
OUTPUT SHAFT
INPUT SHAFT
CLUTCH HUB
PLANET CARRIER
INPUT SUN GEAR
CLUTCH FLANGE
LOW SUN GEAR
REVERSE RING GEAR

43-14. The addition of three more pinions and a clutch provides a neutral and reverse to the low and high gearing.

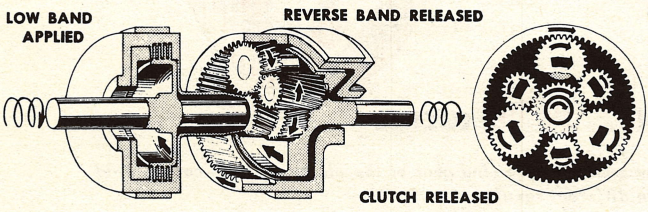
mission in order to be able to back up. The addition of a clutch and reverse gear is shown in Fig. 43-14.

METHOD OF OPERATION

The operation of such a two forward speed and reverse planetary transmission is shown in Figs. 43-15 to 43-18, inclusive. In each case the rotation of each gear is shown by light arrows, while the rotation of the gear assembly is shown by heavy arrows.


LOW BAND RELEASED
REVERSE BAND RELEASED
CLUTCH RELEASED

43-15. In the neutral position the planet carrier which is attached to the propeller shaft is standing still while all the gears rotate around it.


LOW BAND APPLIED
REVERSE BAND RELEASED
CLUTCH RELEASED

43-16. In the low speed position the planet carrier and the gears are all revolving but at different relative speeds.

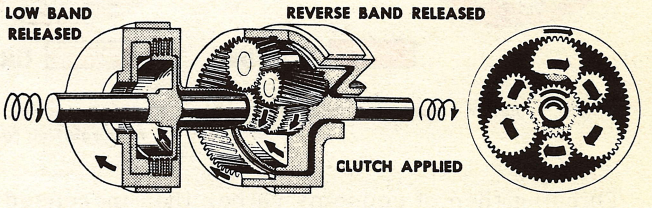
These diagrams and explanations are well worth considerable study. A thorough understanding of all these gear actions is absolutely necessary in order to be able to understand the operation of the more complicated automatic transmissions to be studied later. As an example of the need for understanding of the principles involved, consider the planetary gear as used for an overdrive. Here we want to increase the gear ratio instead of reducing it.

OTHER ADAPTATIONS

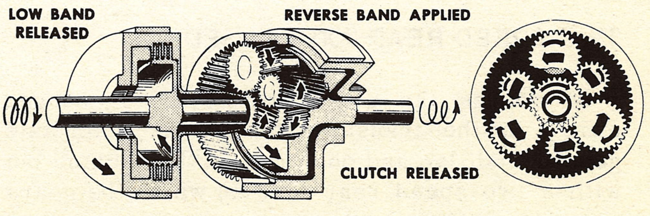
Using the same fundamental gears we used for the planetary transmissions, we can change the hook-up to get an overdrive. If we attached the engine or driveshaft to the planet carrier instead of the sun gear and the propeller shaft or driven-shaft to the ring gear instead of the planet carrier, we would change the entire operation. By holding the sun gear from rotating we could then reverse the action of the gearing and get an increase in gear ratio instead of a reduction. Also see Fig. 43-19. This will be considered more fully under the subject of "overdrives."

TRANSMISSION OVERDRIVES

In an earlier chapter we discussed the first sliding gear transmission and found that the


LOW BAND RELEASED
REVERSE BAND RELEASED
CLUTCH APPLIED

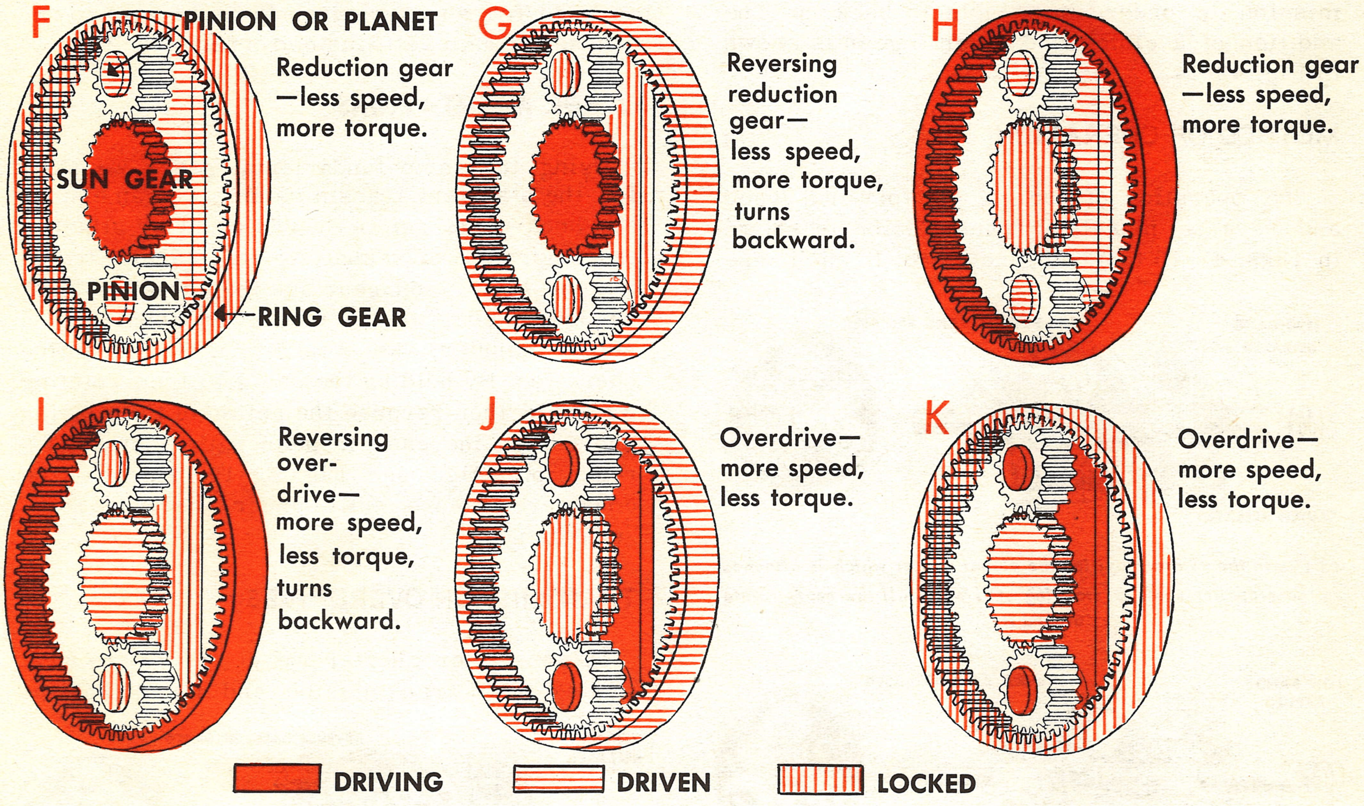
43-17. In the high gear or direct drive, everything turns and the speed of rotation of the output or propeller shaft is the same as the speed of the input or engine shaft.


LOW BAND RELEASED
REVERSE BAND APPLIED
CLUTCH RELEASED

43-18. In the reverse position the ring gear stands still and the planet carrier rotates in the opposite direction.

high gear was overgeared. That is, the propeller shaft turned faster than the engine shaft. As this was noisy, engineers soon developed the previously discussed method of a direct connection between the driving and driven shafts which eliminated the need for transmitting power through the countershaft gears. This of course resulted in equal speed for the driving and driven shafts.

As automobiles were further refined and became more reliable, more attention was paid to economy of operation. Engine sizes were reduced and car weight was reduced with a consequent improvement in gasoline mileage. Thinking then of economy rather than increased speed, it was felt that the improvement in roads made it desirable to have a higher gear ratio available for use when conditions permitted.


F
PINION OR PLANET
Reduction gear —less speed, more torque.
SUN GEAR
PINION
RING GEAR
G
Reversing reduction gear— less speed, more torque, turns backward.
H
Reduction gear —less speed, more torque.
I
Reversing over-drive— more speed, less torque, turns backward.
J
Overdrive— more speed, less torque.
K
Overdrive— more speed, less torque.
DRIVING
DRIVEN
LOCKED

43-19. Any one of the three units in a planetary gear set—the sun gear, the ring gear or the planet carrier—can be held from rotation to obtain different results.

TWO-SPEED REAR AXLES USED

Of course the gear ratio could be changed either in the transmission or the rear axle gears. Cadillac and one or two others came out with a two-speed rear axle in which the gears could be shifted while the car was in motion. About the same time accessory makers developed attachments or replacements for some of the more popular cars which provided two gear ratios in the rear axle.

Two-speed axles which were expensive and heavy were discarded for passenger car use but are widely used today in trucks. As the extra weight of the two-gear units was added to the axle, it was what the engineers call "un-sprung" weight. That is, the weight was not supported by the car springs. Engineers try to hold down on the weight of all parts not supported by the springs in order to make the car ride better and hold the road better. In fact this was one of the principal reasons for mounting the transmission on the frame or engine instead of on the rear axle as some makers did in the early days.

OVERDRIVE AND FREE-WHEEL

The two-speed axle was used for a time and then eventually someone worked out the answer to the overdrive problem. It was the combination of planetary gears with a free-wheel clutch. This combination was light in weight, not too expensive to build and could be attached to the transmission where it would be carried by the car springs as part of the sprung weight. Furthermore it could be easily controlled by the driver and could be made automatic in operation.

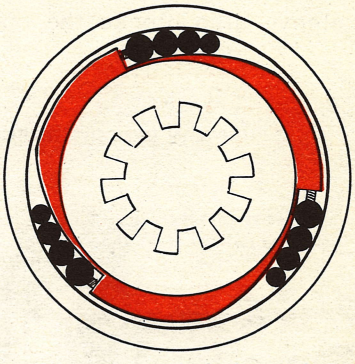
ARRANGING OVERDRIVE

We have now studied several ways of hooking up planetary gearing to accomplish different results. One method was to obtain an increase in gear ratio by attaching the driven shaft to the ring gear and holding the sun gear from rotating. Now however when we release the sun gear the pinions will simply chase around between the sun gear and ring gear in the opposite direction and no power will be transmitted.

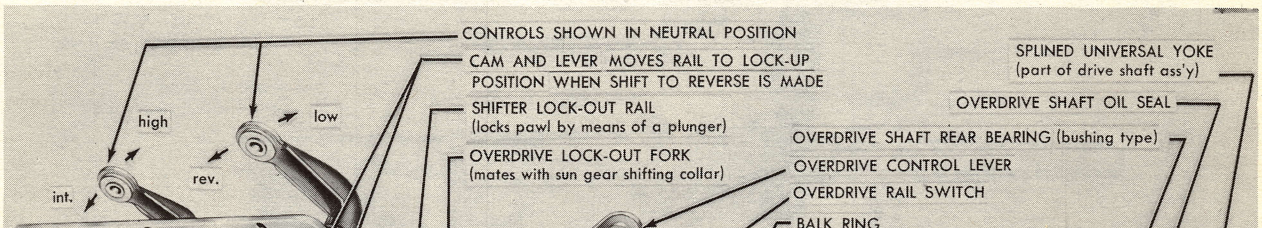
But by installing a free-wheel clutch on the transmission main shaft this reversal of rotation cannot occur. When the propeller shaft speed exceeds the engine speed, as when coasting, the rollers release and when accelerating the engine will wedge the rollers on the cam and transmit power. See Fig. 43-20. A cut-away view of such an installation on the transmission is shown in Fig. 43-21, which also shows the control means.

METHODS OF CONTROL

Control must be in the hands of the driver at all times as pointed out previously because of the free-wheeling which can be dangerous unless locked out when descending a steep grade where the braking effect of the engine is needed. Therefore an external sleeve which is shiftable



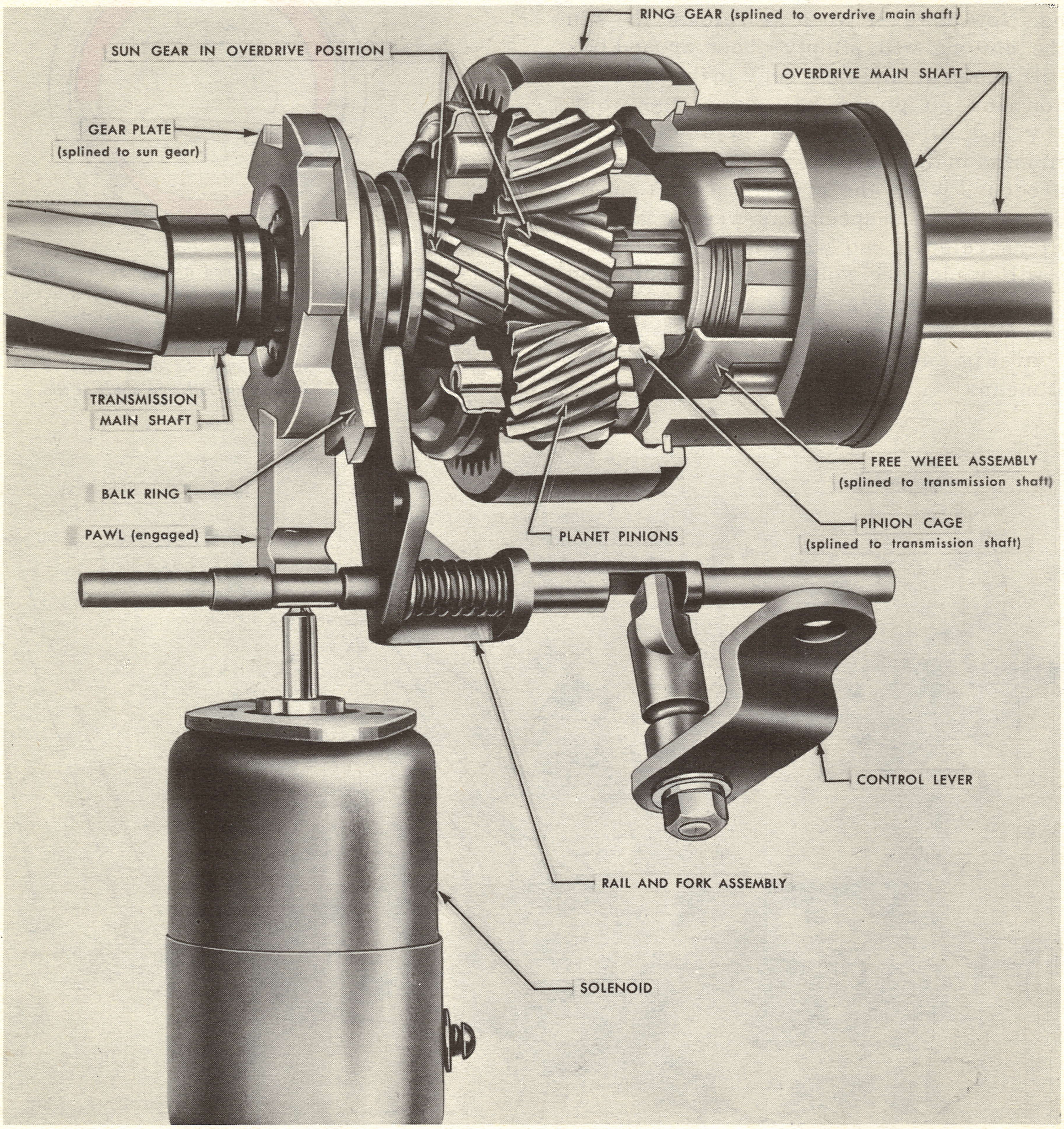
43-20. If the outer rim is turned clockwise the rollers will roll up on the inclined cams and the hub will be turned at the same speed as the rim. If the rim is turned counterclockwise, the rollers will roll down the cams against the springs and the hub will "free-wheel" or cease to rotate because there is no wedging action between the hub and shell or rim.


CONTROLS SHOWN IN NEUTRAL POSITION
CAM AND LEVER MOVES RAIL TO LOCK-UP POSITION WHEN SHIFT TO REVERSE IS MADE
SHIFTER LOCK-OUT RAIL (locks pawl by means of a plunger)
OVERDRIVE LOCK-OUT FORK (mates with sun gear shifting collar)
high
low
int.
rev.
SPLINED UNIVERSAL YOKE (part of drive shaft ass'y)
OVERDRIVE SHAFT OIL SEAL
OVERDRIVE SHAFT REAR BEARING (bushing type)
OVERDRIVE CONTROL LEVER
OVERDRIVE RAIL SWITCH
BALK RING
STATIONARY GEAR PLATE (sliding spline on sun gear)
SUN GEAR WITH SHIFTING COLLAR
TRANSMISSION SHAFT
OVERDRIVE HOUSING
OVERDRIVE SHAFT BEARING COVER AND GASKET
OVERDRIVE MAIN SHAFT BEARING
OVERDRIVE SHAFT
PLATE AND TROUGH ASSEMBLY
CENTRIFUGAL GOVERNOR (helical gear drive)
SPEEDOMETER DRIVE
FREE WHEEL ASS'Y (splined to transmission shaft)
INTERNAL TOOTH RING GEAR (splined to overdrive shaft)
SUN GEAR (slide fit over transmission shaft)
PLANETARY GEARS— (3) (helical type, needle bearing mounted)
PLANET CAGE (splined to transmission shaft)
SOLENOID
OVERDRIVE PAWL
ADAPTER PLATE

43-21. This cut-away illustration shows the entire transmission, overdrive and parts as used on a Mercury automobile.

endwise is attached to a shifting fork connected to a dash control button. Thus the entire overdrive and free-wheel can be locked tight together and the car operates as if there were no overdrive on it.

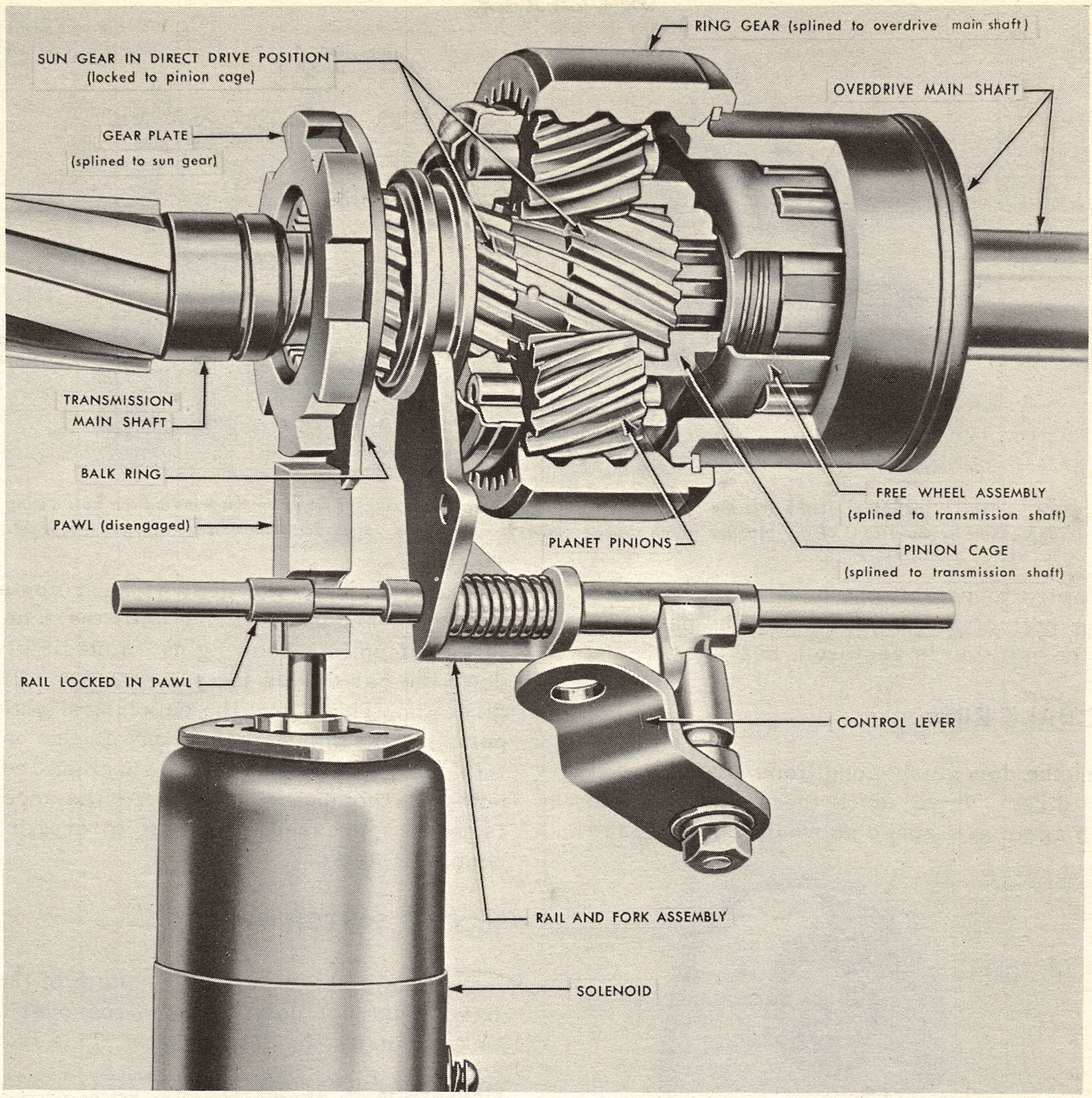
Obviously it would be undesirable to have the sun gear locked in the overdrive position when the shift sleeve or ring gear is moved to lock out the overdrive. Therefore the same rod that shifts the sleeve also blocks the operation of the device to lock the sun gear. This action is shown in Fig. 43-22 and 43-23. Locking of the sun gear is accomplished by an electrical solenoid magnet attached to a plunger or pawl which drops into a slot in the gear plate on the sun gear. See Figs. 43-22 and 43-23.


RING GEAR (splined to overdrive main shaft)
SUN GEAR IN OVERDRIVE POSITION
OVERDRIVE MAIN SHAFT
GEAR PLATE (splined to sun gear)
TRANSMISSION MAIN SHAFT
FREE WHEEL ASSEMBLY (splined to transmission shaft)
BALK RING
PINION CAGE (splined to transmission shaft)
PAWL (engaged)
PLANET PINIONS
CONTROL LEVER
RAIL AND FORK ASSEMBLY
SOLENOID

43-22. Cut-away of overdrive assembly in position for overdrive operation.

SOLENOID MAGNET OPERATION

The solenoid consists of an iron plunger within coils of wire through which electricity flows. When the current is turned on the iron core moves endwise into the magnetic field and pushes the pawl into engagement. A typical solenoid is shown in Fig. 43-24. In this case there are two coils of wire. A heavy winding to move the plunger and a lighter winding to hold it in place after it is moved. Both coils are


RING GEAR (splined to overdrive main shaft)
SUN GEAR IN DIRECT DRIVE POSITION (locked to pinion cage)
OVERDRIVE MAIN SHAFT
GEAR PLATE (splined to sun gear)
TRANSMISSION MAIN SHAFT
BALK RING
PAWL (disengaged)
FREE WHEEL ASSEMBLY (splined to transmission shaft)
PLANET PINIONS
PINION CAGE (splined to transmission shaft)
RAIL LOCKED IN PAWL
CONTROL LEVER
RAIL AND FORK ASSEMBLY
SOLENOID

43-23. Cut-away view of overdrive assembly in direct drive position when planetary gears do not function.

used to move the plunger which as it goes down opens the contacts for the closing coil and leaves the holding coil in operation.

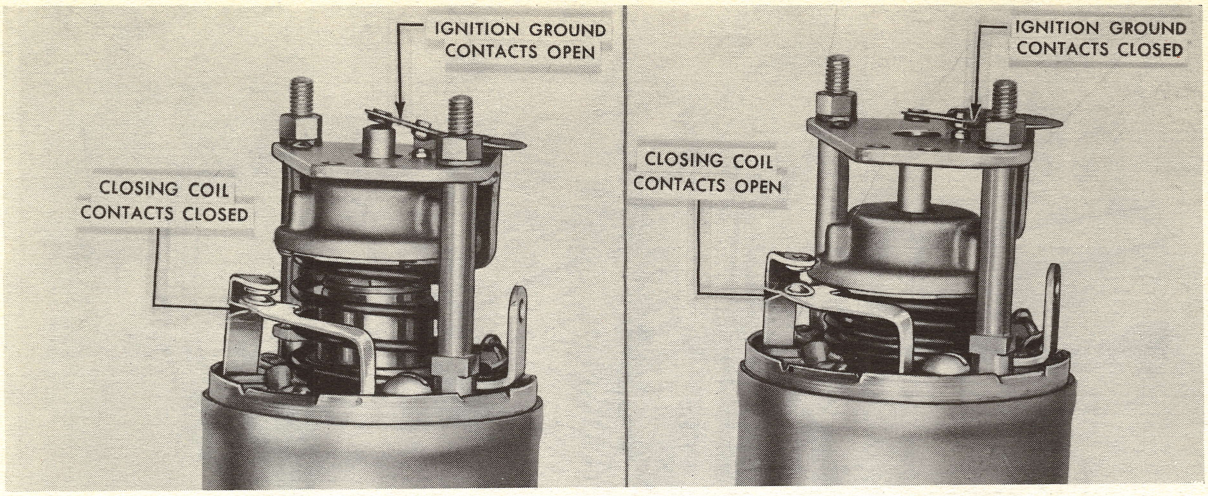
MECHANICAL GOVERNOR OPERATION

As it is desirable to have the overdrive function above a car speed of about 25 miles per hour (m.p.h.) and undesirable to have it in use below that speed, some automatic device is needed to connect it and disconnect it. Otherwise the driver would have to manipulate the controls repeatedly when driving in traffic. This is accomplished by a mechanical centrifugal governor which operates an electrical switch to control the flow of electricity to the solenoid.

This overdrive governor is geared to and driven by the propeller shaft. The construction of a typical governor is shown in Fig. 43-25. Centrifugal force causes the weights to tend to fly outward and raise a floating shaft which closes the contact points in the cover. The governor is designed and adjusted to close at a somewhat higher speed than it opens. If it opened and closed at the same identical speed it would be opening and closing continuously if the car were driven at that exact speed.

KICKDOWN SWITCH NEEDED

At times it is desirable to change temporarily from overdrive to direct drive as when climbing a hill or accelerating to pass another car. For this purpose an electrical switch is located under the foot accelerator. Pushing the pedal all the way will close the contacts and cut out the overdrive. When the pedal is pushed down all the way it also shorts out the ignition

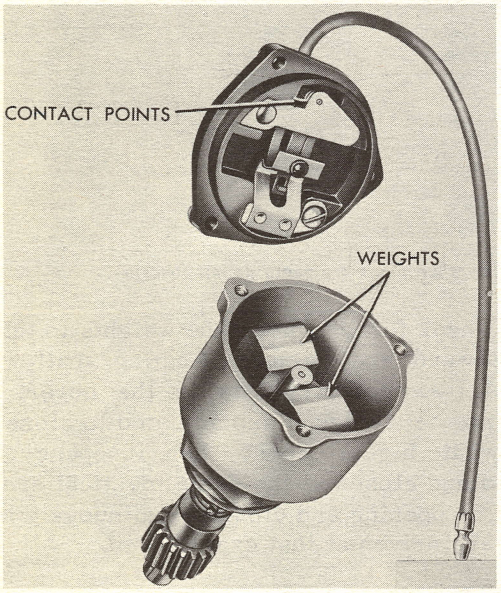

IGNITION GROUND
CONTACTS OPEN
CLOSING COIL
CONTACTS CLOSED
IGNITION GROUND
CONTACTS CLOSED
CLOSING COIL
CONTACTS OPEN

43-24. In this illustration at the left the solenoid is not energized. When current flows in the winding the coil spring is depressed by movement of the plunger which closes contacts on top and opens contacts at side as shown at right.

momentarily to permit the pawl to be released from the pull of the engine. When the pawl releases the ignition is restored. See Fig. 43-26.

USE OF BALK RING

Under the foregoing conditions the car will stay in direct drive until the accelerator is eased up again at a speed above the cut-in speed of about 25 m.p.h. which permits the balk ring to line up the notch in the gear plate for the pawl to enter. This balk ring is shown in Figs. 43-22 and 43-23. It is intended to avoid harsh and sudden locking of the sun gear. It is a friction fit on the gear plate and does not revolve.

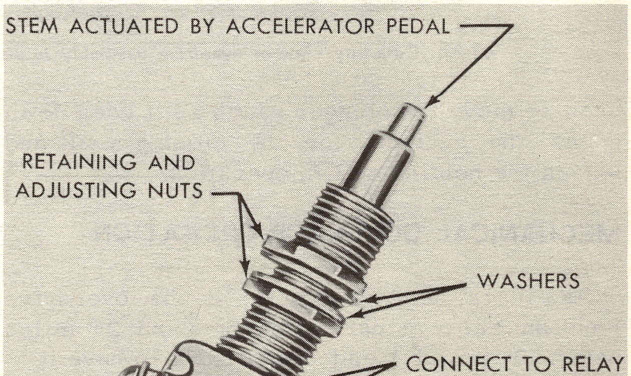

CONTACT POINTS
WEIGHTS

43-25. A typical governor construction showing contacts closed by floating shaft between the weights.

When the solenoid plunger starts to engage the slot in the sun gear it first contacts the balk ring and stays there until the accelerator is eased up. As the engine immediately slows down the car drives the sun gear in the reverse direction. This turns the balk ring slightly which permits the plunger to drop off the balk ring into the gear plate without shock as the engine power is not being applied. As the accelerator is next depressed the shift to overdrive has been completed.

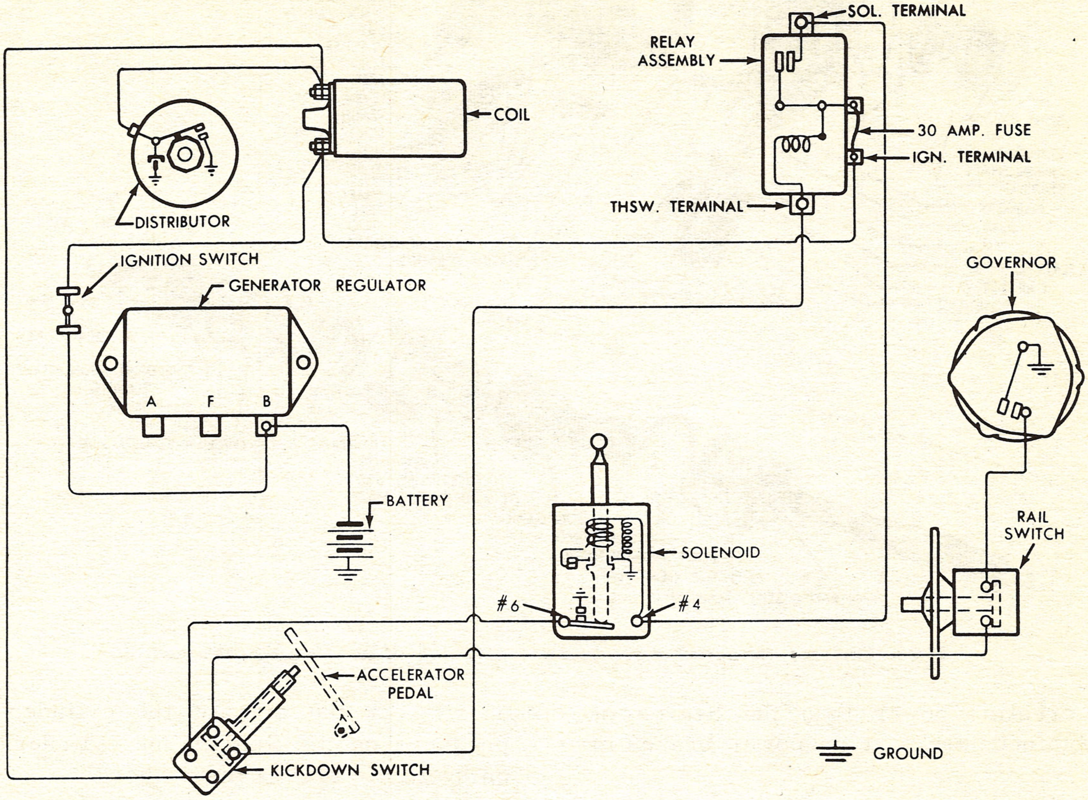
MASTER SWITCH NEEDED

Obviously the electrical system of the overdrive must not operate when the overdrive is locked out by the dash control. This is accom-


STEM ACTUATED BY ACCELERATOR PEDAL
RETAINING AND
ADJUSTING NUTS
WASHERS
CONNECT TO RELAY
AND RAIL SWITCH
CONNECT TO IGNITION COIL
AND #6 SOLENOID TERMINAL

43-26. Typical kickdown switch.

plished by placing a master switch or "rail switch" in the circuit between the governor and the other parts. This switch is controlled by the dash button and locks the pawl out in addition to opening the electrical circuit. Thus the overdrive is inoperative above the cut-in speed as well as below. See Fig. 43-27 which shows the electrical connections and circuits for all units of the overdrive system. For details of the mechanical parts see the exploded view Fig. 43-28.



43-27. Wiring diagram showing electrical units and method of connecting.

POWER OPERATED SHIFTING DEVICES

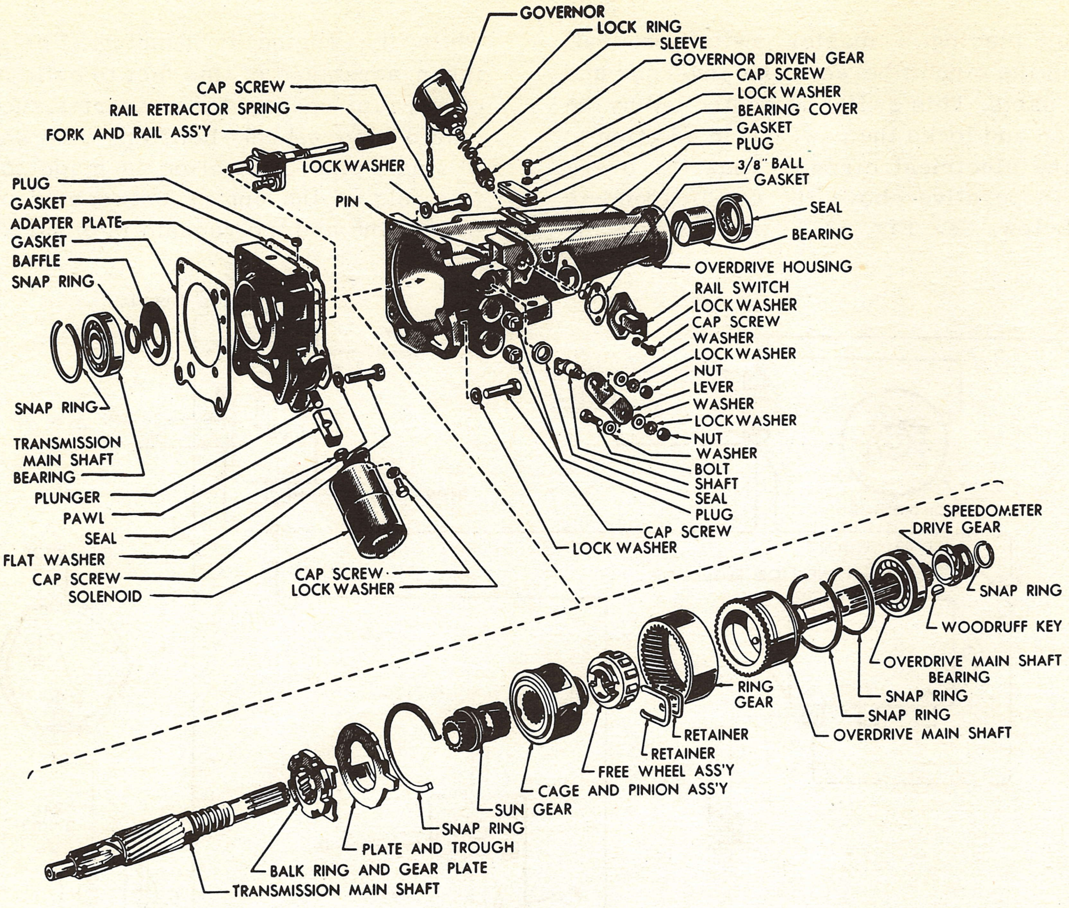
In our study of overdrives, we have seen how electrical solenoids are used to hold and release the planetary sun gear and thus control the overdrive. The construction details of a solenoid magnet are shown in Fig. 43-29. Solenoids are used extensively, as control devices for vacuum and hydraulic power devices which do the actual shifting.

OPERATION OF VACUUM CYLINDERS

As an automobile engine is also a vacuum pump there is always vacuum power available while the engine is running. Designers have taken advantage of this fact to build a multitude of vacuum operated accessories such as windshield wipers, brake boosters, gear shifters, etc. A small pipe connection is made to the intake manifold of the engine between the carburetor and engine and the vacuum is piped to wherever it is wanted.

Now it must be understood that the unaided suction thus derived from the engine through a small pipe is not powerful enough to apply brakes and shift gears. The suction is used to create air power which does the actual work. The amount of power created in this fashion is directly dependent upon the size of the diaphragm in the vacuum cylinder upon which the air pressure acts.

The air pressure at sea level is about 15 pounds per square inch (p.s.i.), so if we have a complete vacuum in a cylinder containing a diaphragm there should be a pressure on the other side of the diaphragm amounting to the number of square inches of diaphragm surface multiplied by 15 lbs. As the surface of a circle increases in proportion to the square of the diameter increase, it will be apparent that the size of the diaphragm is of much more impor-


GOVERNOR
LOCK RING
SLEEVE
GOVERNOR DRIVEN GEAR
CAP SCREW
LOCK WASHER
BEARING COVER
GASKET
PLUG
3/8" BALL
GASKET
SEAL
BEARING
OVERDRIVE HOUSING
RAIL SWITCH
LOCKWASHER
CAP SCREW
WASHER
LOCKWASHER
NUT
LEVER
WASHER
LOCKWASHER
NUT
WASHER
BOLT
SHAFT
SEAL
PLUG
CAP SCREW
LOCK WASHER
CAP SCREW
RAIL RETRACTOR SPRING
FORK AND RAIL ASS'Y
LOCKWASHER
PIN
PLUG
GASKET
ADAPTER PLATE
GASKET
BAFFLE
SNAP RING
SNAP RING
TRANSMISSION MAIN SHAFT BEARING
PLUNGER
PAWL
SEAL
FLAT WASHER
CAP SCREW
SOLENOID
CAP SCREW
LOCK WASHER
SPEEDOMETER DRIVE GEAR
SNAP RING
WOODRUFF KEY
OVERDRIVE MAIN SHAFT BEARING
SNAP RING
SNAP RING
OVERDRIVE MAIN SHAFT
RING GEAR
RETAINER
RETAINER
FREE WHEEL ASS'Y
CAGE AND PINION ASS'Y
SUN GEAR
SNAP RING
PLATE AND TROUGH
BALK RING AND GEAR PLATE
TRANSMISSION MAIN SHAFT

43-28. Exploded illustration of overdrive assembly with all parts in proper relation.

tance in creating power than the degree of vacuum obtained. See text on power brakes in this book.

AUTOMATIC TRANSMISSION

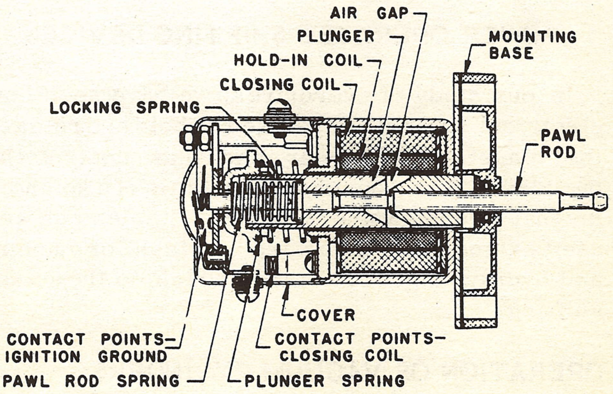
Obviously we can attach a vacuum cylinder to the brake pedal and operate the brakes, or to the clutch pedal and operate the clutch. Also we can hitch it to the gear shift lever and shift the gears. We can put one on the clutch and another on the gear shift lever and with suitable controls obtain automatic operation of the gear shifting.

HYDRAULIC CYLINDERS

Hydraulic pressure is utilized also for shifting gears and in the control of automatic transmissions. By using an oil pump driven by the engine we can obtain almost any amount of hydraulic pressure or power we need. This power can be easily piped to any point where required. The amount of pressure can be controlled by spring loaded valves. Thus by virtue of the fact that a fluid under pressure expands equally in all directions we can control the power exerted by the size of the cylinder and the pressure on the fluid in the cylinder. See text on hydraulic brakes in this book.

CHOICE OF AUTOMATIC TRANSMISSIONS

It will now be clear that we have a choice of several ways to approach an automatic transmission. There are a number of other automatic


AIR GAP
PLUNGER
HOLD-IN COIL
CLOSING COIL
LOCKING SPRING
MOUNTING BASE
PAWL ROD
COVER
CONTACT POINTS-IGNITION GROUND
CONTACT POINTS-CLOSING COIL
PAWL ROD SPRING
PLUNGER SPRING

43-29. Cross section of typical solenoid magnet showing how plunger moves within the coils.

transmission types in European automobiles in more or less experimental form. We have confined this text to passenger car production types in the U. S. A.

A. We can use electricity, air pressure or hydraulic pressure for either or both the clutch and transmission. We can also combine each of the three sources of power with the others.
  1 - To shift a sliding gear transmission.
  2 - To operate the clutch.
  3 - To operate a planetary transmission.
B. We can use a fluid flywheel instead of a power operated clutch. (The results are not identical however).
C. We can combine various elements of the above to obtain automatic operation.
D. We can use a hydraulic torque converter instead of some of the gearing or in combination with gearing and with or without a clutch.

TRANSMISSION LUBRICATION SPUR AND HELICAL GEARS

It will be apparent that lubrication will be required for the gear teeth, the bearings upon which the shafts turn, the splines upon which the gears slide and the other parts. Therefore, the gear case is made oil tight by placing gaskets between the case and cover and any other parts that are bolted to the case. Oil seals are also placed at each of the bearings on the mainshaft. The rotation of the gears throws the oil all over the inside of the case at any time the clutch is engaged.

If oil escaped along the pinion shaft into the clutch, it would ruin the clutch facing in addition to the loss of oil. The oil used is heavier than engine oil in most cases and is known as SAE80 or 90 Gear Oil. Heavy engine oil (SAE50 or 60) can be successfully used in transmissions if the case and bearings are really oil-tight. The case is not filled with oil to the top but to the level of the fill plug which is usually slightly below the countershaft.

Sometimes the rotation of the gears will act as a pump to generate pressure inside the transmission case and tend to force the oil out. In such cases a vent is placed in the top of the case to let the pressure escape. A more common cause of oil leakage is the oil level being too high in the case. This and additional causes of oil leakage and troubles of various sorts are common to both the straight spur gear transmission and the helical gear and synchro-mesh transmissions and will be considered under transmission "Trouble Shooting."

PLANETARY GEARS

Very little attention is required by modern planetary gear sets as they have been improved in design and better materials are now available. At one time the brake band linings were inclined to wear out quite rapidly and require replacement. They were also subject to surface glazing and hardening which caused considerable chatter and noise. Band linings are now made of better material and lubrication has been improved.

When used in automatic transmissions, the light oil used in the transmission housing is a satisfactory lubricant for the gears, bearings and bands of the planetary set. When planetary gears are used in an overdrive, no bands are required and the gear oil used in the transmission housing is satisfactory in most cases. Trouble may be experienced if some types of extreme pressure lubricants are used in an overdrive. This is because the planet gears operate at very high speed and act as a centrifuge (like a cream separator) to separate the additives from the oil. The tooth pressures in planetary gearing are low and an extreme pressure lubricant is not required. Engine oil SAE60 or Transmission oil SAE80 are ideal lubricants for overdrives.

TRANSMISSION TROUBLE SHOOTING

SPUR AND HELICAL GEARS

TRANSMISSION NOISY IN NEUTRAL

This may be a growl or hum that can be stopped by depressing the clutch pedal. In some cases a bump or thud also will be present indicating a broken gear or bearing. Defects in the mainshaft, other than the pilot bearing on the front end of the mainshaft are not included in this group as the mainshaft does not rotate when transmission is in neutral.

1 - Insufficient lubricant in transmission.
2 - Abnormal end play in countershaft gears, reverse idler gear or pinion shaft.
3 - Pinion gear badly worn or broken.
4 - Pinion shaft bearing badly worn or broken.
5 - Misalignment between engine and transmission.
6 - Wear in countershaft drive gear.
7 - Wear in reverse and/or reverse idler gear.
8 - Countershaft bearings badly worn.
9 - Reverse idler shaft bearings badly worn.

10 - Countershaft sprung or bent.
11 - Pilot shaft bearing worn or broken.

NOTE: If replacement of a gear is required, the gear with which it mates should also be replaced. A new gear and an old one running together are almost sure to be noisy.

TRANSMISSION NOISY IN GEAR:

Most of the foregoing list of noises will also appear when the transmission is in gear as the same parts are still in operation plus the mainshaft which adds the following:

1 - Mainshaft rear bearing worn or broken.
2 - Sliding gears badly worn or broken.
3 - Excessive end play of mainshaft.
4 - Badly worn speedometer gears.

TRANSMISSION SLIPS OUT OF HIGH GEAR:

The principal cause is misalignment between the transmission and the engine. The front end of the pinion shaft runs in a bearing in the flywheel and the rear end in the transmission case. If this shaft is not in a straight line with the engine crankshaft and the transmission mainshaft it will create an angular contact between the mating high gear dogs or jaws and cause them to separate. Other less frequent causes are:

1 - Pinion gear teeth worn or tapered.
2 - Pinion gear bearing badly worn.
3 - Improper adjustment of shift linkage.
4 - Worn shift detent parts.

TRANSMISSION SLIPS OUT OF SECOND GEAR:

1 - Badly worn or broken gear.
2 - Badly worn transmission bearings.
3 - Improper adjustment of shift linkage.
4 - Worn shift detent parts.
5 - Excessive end play of main or countershaft.

TRANSMISSION SLIPS OUT OF FIRST OR REVERSE GEAR:

1 - Badly worn or broken gears.
2 - Badly worn transmission bearings.
3 - Mainshaft splines worn or distorted.
4 - Excessive end play of main, countershaft or reverse idler shaft.
5 - Worn shift detent parts.
6 - Improper adjustment of shift linkage.

TRANSMISSION DIFFICULT TO SHIFT:

1 - Engine clutch not releasing.
2 - Distorted or burred mainshaft splines.
3 - Improper adjustment of shift linkage.

TRANSMISSION OIL LEAKS:

1 - Damaged oil seals.
2 - Damaged oil throw rings.
3 - Damaged or missing gaskets.
4 - Case or cover bolts loose or missing.
5 - Case plugs loose or threads stripped.
6 - Oil level too high.
7 - Vent stopped up.
8 - Use of a lubricant that foams excessively.

PLANETARY TROUBLE SHOOTING

GROWLING OR HUMMING NOISES:

1 - Insufficient lubricant in housing.
2 - Dragging brake bands.
3 - Excessive wear in gear teeth.
4 - Excessive wear in gear bushings or shafts.

ROUGH OR HARSH ENGAGEMENT:

1 - Glazed or burned band linings.
2 - Lubricant excessively thin.
3 - Scored drums.
4 - Improper adjustment of band operating device.
5 - Burned or gummed clutch plates.

GRINDING OR CLICKING NOISES:

1 - Excessive wear in gears.
2 - Damaged gear teeth.
3 - Worn bushings or broken needle bearings.
4 - Insufficient lubricant.
5 - Excessive wear in clutch hub or drum driving pins or slots.

SLIPPING OR SLOW ENGAGEMENT:

1 - Bands too loose.
2 - Improper adjustment of band operating device.
3 - Scored or burned drums.
4 - Scored or burned band linings.
5 - Warped, scored or burned clutch plates.
6 - Clutch plates sticking on hub or in drum.

OVERDRIVE TROUBLE SHOOTING

When attempting to diagnose trouble with an overdrive it must be borne in mind that the trouble can be caused by electrical defects, mechanical defects or a combination of both. As electrical troubles are more likely to occur, it is usually desirable to check the electrical system first and eliminate any defects before going on to mechanical difficulties. Electrical troubles can occur in the units such as the relay, solenoid, governor, rail switch or kickdown switch or in any of the wires connecting these units. The most common trouble is loose or dirty connections on the wiring terminals. Any wire or connection can be tested with electrical meters or by temporary substitution of a "jumper" or test wire.

OVERDRIVE DOES NOT ENGAGE:

1 - Fuse blown on relay.
2 - Defective connecting wires, loose or

corroded terminals.
3 - Defective relay unit.
4 - Defective solenoid.
5 - Defective governor contacts.
6 - Defective rail switch.
7 - Defective kickdown switch.
8 - Dash control improperly adjusted.
9 - Governor gear drive pin sheared.
10 - Damaged gears, bearings or shifting parts within the overdrive unit requiring removal and inspection of the assembly.

OVERDRIVE DOES NOT RELEASE:

1 - Defective relay unit.
2 - Defective connecting wires, loose or corroded terminals.
3 - Defective rail switch.
4 - Sticking, bent or damaged pawl.
5 - Defective kickdown switch.
6 - Damaged gears, shafts or shifting parts within the overdrive unit requiring removal and inspection of the assembly.

KICKDOWN DOES NOT OPERATE:

1 - Kickdown switch improperly adjusted.
2 - Loose or corroded terminals or defective connecting wires.
3 - Defective operation of contacts in solenoids.
4 - Defective kickdown switch.

ENGINE STOPS WHEN KICKDOWN IS USED:

1 - Defective kickdown switch.
2 - Ground in wiring or solenoid.

CAR WILL NOT REVERSE:

1 - Shift rail operation defective.

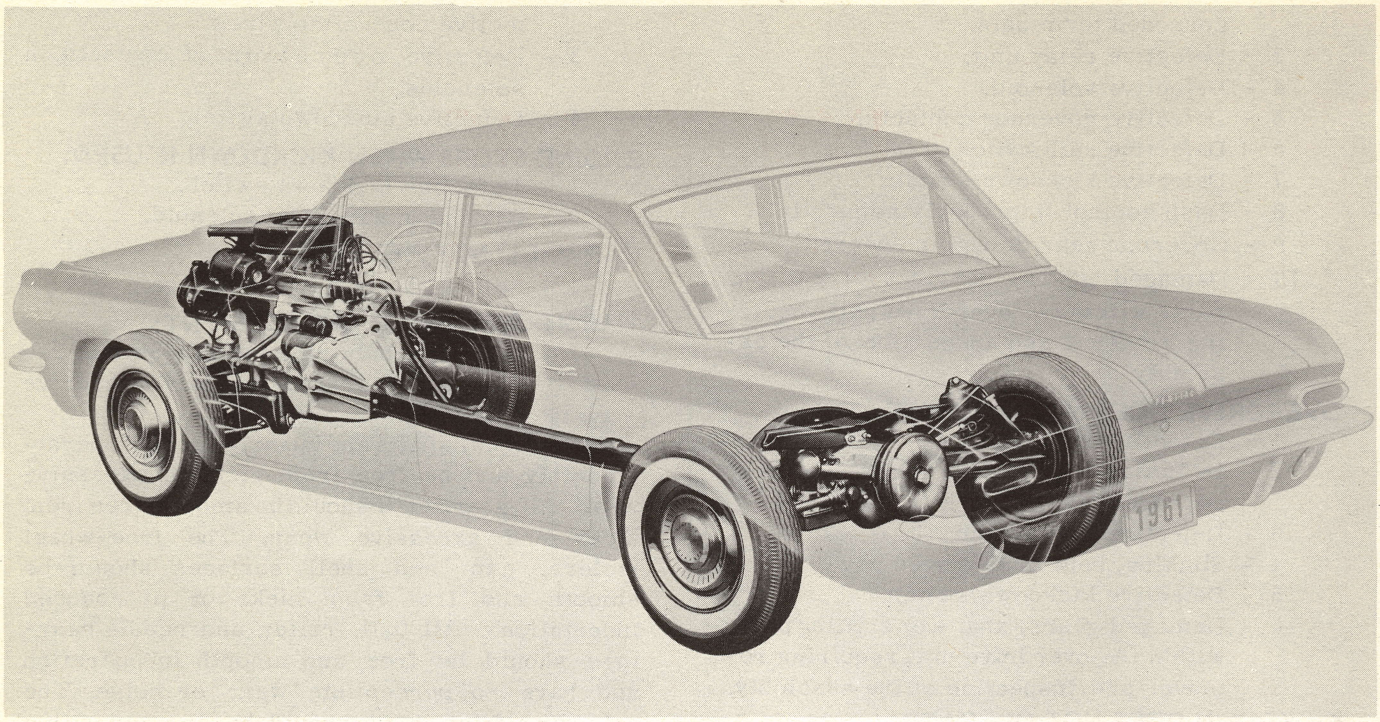
HARSH OVERDRIVE ENGAGEMENT:

1 - Defective balk ring action requiring removal and disassembly of overdrive assembly.

All splines, shafts and bushings should operate smoothly and be free from nicks or excessive wear. All gear teeth should be smooth, free from nicks and excessive wear. The free-wheel rollers, cam and shell surfaces should be smooth and free from nicks or pronounced indentations. All ball, roller and needle bearings should be free and smooth in operation and have no perceptible wear or noise. The balk ring friction fit should be checked with a spring scale and replaced if not within the friction limits specified by the manufacturer.

QUIZ - AUTOMOBILE TRANSMISSIONS

1. A larger gear on the driving shaft will increase the speed of rotation of the driven shaft. True---, false---.
2. How can the ratio of a pair of gears be determined?
3. When the engine is running and the clutch engaged on a sliding gear transmission, the countershaft turns continuously. True---, false---.
4. In a planetary gear set, all gears are in mesh at all times. True---, false---.
5. Name the three units of a planetary gear set.
6. If the sun gear is driven and the ring gear held, the result will be a gear reduction. True---, false---.
7. If the ring gear is driven and the sun gear held, the result will be less torque and more speed. True---, false---.
8. If the pinion carrier is driven and the sun gear held, what is the result?
9. How is a gear reduction obtained in reverse by driving the sun gear? By holding the ring gear---, the planet carrier---.
10. Is there more than one way of obtaining reverse rotation of a planetary gear set, Yes---, No---.
11. Describe a solenoid magnet.
12. What is the purpose of a balk ring in a transmission overdrive?
13. Why are some extreme pressure lubricants unsuitable for use in planetary gear overdrives?
14. Name three causes for a sliding gear transmission slipping out of high gear.
15. Name four causes of slippage in a planetary gear set.



Front engine-rear transmission arrangement as used by Pontiac Tempest.

HYDRAULIC TRANSMISSIONS

All current hydraulic transmissions consist of:

A - One or more sets of planetary gears.

B - One or more fluid couplings which transmit power but do not increase or decrease torque; OR a torque converter with one or more turbines which do increase torque. It is also possible to position a reactor between the turbine and impeller of a fluid coupling in such manner that the results will be a combination of fluid coupling and torque converter action.

C - Suitable valves to direct the flow of the hydraulic fluid.

D - Various combinations of valve actuation.

AUTOMATIC TRANSMISSION CONTROL

One means of mechanical control is to connect a valve to a hand lever operated by the driver.

Another means of mechanical control is to connect a valve to the foot accelerator so that the demands of the driver as expressed by pressure on the engine throttle will operate the valve automatically.

Action of a control valve may be regulated automatically by the load on the engine by connecting a valve to the engine intake manifold because the vacuum in the manifold decreases as the load on the engine is increased.

A valve or valves may be operated hydraulically by means of oil pressure generated in the engine or in the transmission by oil pumps.

Engine speed may be used to operate control valves by connecting them to speed-sensitive governors on the engine.

In the same manner, the car speed can control a valve if the governor is attached to the drive shaft of the automobile.

Any of these valves may be opened or closed entirely or partially, slowly or rapidly.

In addition to mechanical, hydraulic and vacuum operation, we can connect almost any type of electrically operated device to the electrical system of the car.

Several of these devices can be combined in a control system in order to obtain almost any kind of automatic control--or degree of automatic control--desired. It is also possible to attach more than one control to a single valve in order to balance the action.

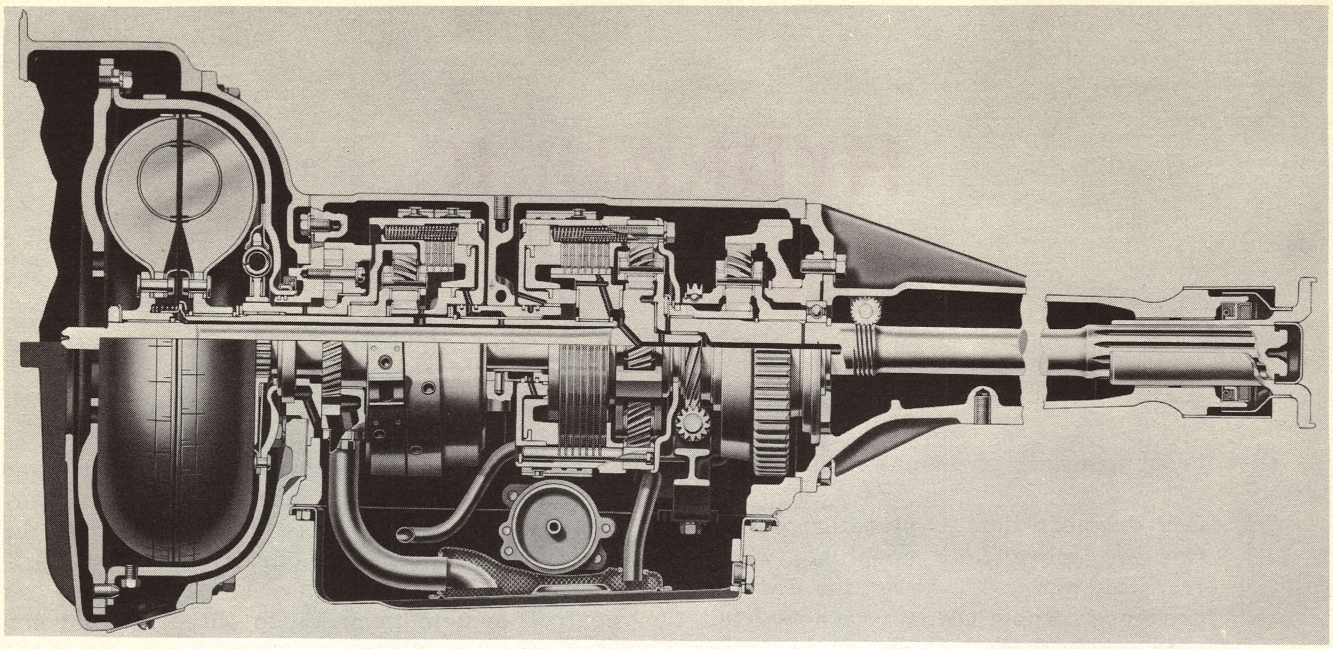
For example; a valve might have dual controls: one to the foot accelerator and another to the intake manifold. In this case a valve might be opened or closed by movement of the accelerator PROVIDED the engine was under light load, but if the engine was under heavy load, the valve action might be delayed by the interconnected vacuum control until the engine load decreased.

By so connecting different controls to the valves in the transmission, adjustment to speed, load and the demands of the driver are automatically made in the transmission ratios.

DESIGN AND CONSTRUCTION

We shall study herein various typical units of design and construction in order that our understanding of operation will be complete. It may be readily understood that the extremely wide variations both between different makes and between different models of the same make preclude any possibility of detailed and explicit repair and trouble shooting procedures on automatic transmissions. Complete repair manuals are readily available for any specific model or for all models and will be needed in case of extensive repair or overhaul procedures.

The availability of these manuals does not however indicate that the following material can be treated lightly. Many of these manuals do not cover the operating principles and therefore unless the user has a thorough understanding of just how automatic transmissions function, he will have little, if any, ability to make repairs



44-1. *Earlier type of Hydra-Matic transmission.*

and adjustments in a satisfactory manner. Time spent in studying the material herein will be found to be an excellent investment.

HYDRA-MATIC TRANSMISSION

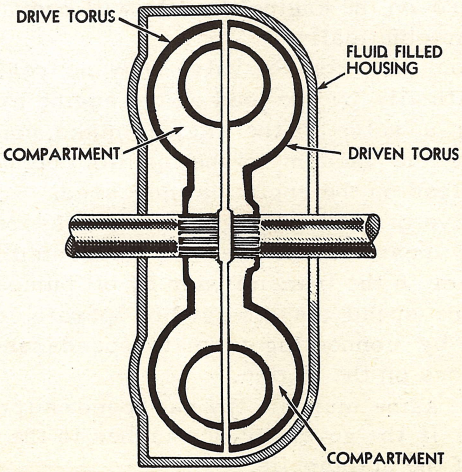
The Hydra-Matic transmission is as its name implies a hydraulically operated automatic transmission. It has been used for several years by a number of different makes of automobiles. Basically the Hydra-Matic is rather simple as it consists of a fluid flywheel attached to two planetary gear units one behind the other and connected in series. See Fig. 44-1.

The built-in control system is a combination of balanced pressures depending upon car speed, engine speed and the demands of the driver expressed through the foot accelerator. The control system is tremendously complicated, but most of the complication is in the design and does not need to be too much of a problem to the service man once he understands the operation of the system and how to test and adjust the regulating devices.

If the reader of this book has a thorough understanding of planetary gearing, fluid flywheels and hydraulic pressure controls as covered in the preceding several chapters, he should have no difficulty in understanding the Hydra-Matic. If however, the reader is somewhat hazy on the operating principles of these previous units, it will be a waste of time and utterly confusing to him to attempt to go any further with this study of automatic transmissions. In fact it is desirable to frequently review some of the preceding chapters to keep the theory of operation clearly in mind.

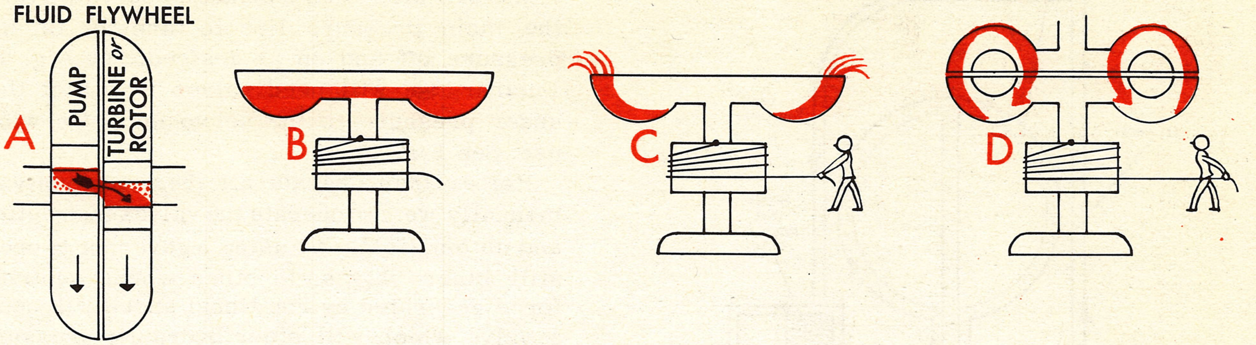
ALTERATIONS TO FLUID FLYWHEEL

The fluid flywheel used with the earlier Hydra-Matic is similar to the basic model explained in a previous chapter, but it has been altered somewhat for use in this assembly. First of all it operates full of fluid instead of partially full and the oil circulates through it from the transmission instead of being sealed up as an individual unit. See Fig. 44-2. Also an inner shell and outer vanes have been added to both the driving torus and driven torus in order to better control the action of centrifugal force on the oil.



44-2. *The Hydra-Matic fluid flywheel is full of fluid at all times when the engine is running.*

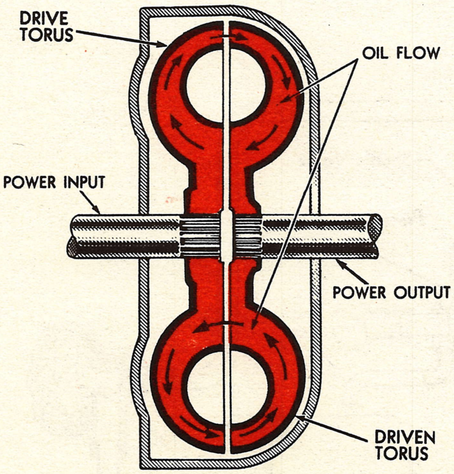
This action can be compared to a shallow round bowl placed on a spinning turntable. If water is poured into the center of the bowl it will go outward to the edge and fly up and out due to the action of centrifugal force. Now if we were to invert another identical bowl over the first one the water would upon entering the upper bowl be guided toward the center and drop back in the lower bowl. Thus we would have established a system of circulation for the fluid. This is the action that takes place in the Hydra-Matic fluid flywheel. See Figs. 44-3 and 44-4.



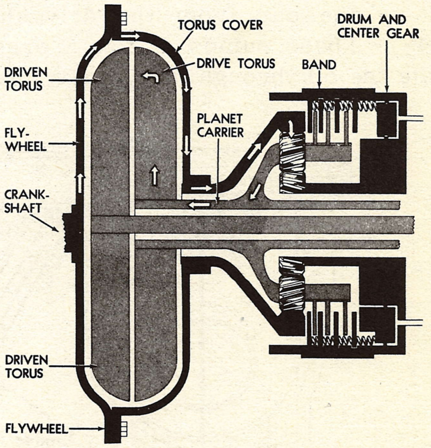
*44-3. **FLUID FLYWHEEL:** A. Inside oil-filled housing of a Fluid Flywheel are the Driving Half or Pump, and Driven Half or Rotor. As driving member is rotated by engine, centrifugal force causes oil to be forced radially outward, cross over and strike vanes of driven member to make it rotate in same direction. The principle of centrifugal force, which establishes axial flow of oil, is explained by Drawings B, C, and D. B. Fluid placed in bowl will lie level. C. If bowl is revolved rapidly, centrifugal force will cause fluid to climb up and spill over outside edge of bowl. D. If another bowl is inverted over first bowl, an axial flow or circuit will be created. After axial flow is set up, driving half, (pump of fluid flywheel) will transmit energy to driven half, or rotor as shown. Torque is thus transmitted, but is not increased.*

At high speed the fluid flywheel is very effective. The loss of speed between the two torus members is probably not over one or two per cent. At low speeds there is considerable slippage and at idling speed almost 100% slippage. There is however some energy transmitted and under some conditions the car may have a tendency to creep slowly as there is no clutch to disengage the idling engine.

To diminish this tendency to creep when the engine is idling, the Hydra-Matic construction is arranged so that the driving torus utilizes the gear reduction of the front planetary unit to turn the driving torus slower than the idling speed of the engine. This is accomplished by placing the driven torus in front of the driving torus instead of behind it and connecting the

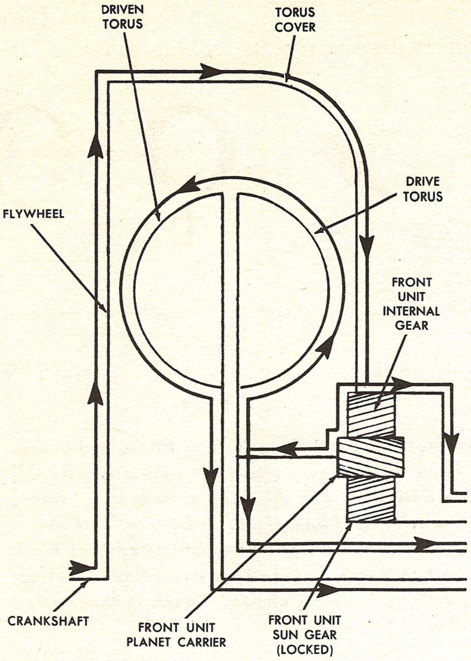


44-4. Each torus member is splined to an independent shaft and the assembly located in an oil-filled housing. In operation, rotation of the driving member causes the oil within it to be forced radially outward. The oil then crosses over and strikes the vanes of the driven member in such a manner as to make it rotate in the same direction as the driving member.



44-5. The power from the engine flywheel is transmitted to the torus cover which is bolted to it. This cover has the dual purpose of enclosing the fluid coupling and transmitting the power from the flywheel to the front unit internal gear (drive gear). With the pinions meshed in the gear, power is passed from the internal gear to the pinions which turn at a reduced speed. Power from the front planet carrier is then transmitted to the driving torus. Make sure you understand how this flow reduces the speed of the driving torus member below the speed of the engine. Refer to charts on Planetary Gears.

engine to the planetary ring gear instead of the driving torus. See Figs. 44-5 and 44-6.


DRIVEN TORUS
TORUS COVER
FLYWHEEL
DRIVE TORUS
FRONT UNIT INTERNAL GEAR
CRANKSHAFT
FRONT UNIT PLANET CARRIER
FRONT UNIT SUN GEAR (LOCKED)

44-6. Power flow through Hydra-Matic from engine crankshaft to transmission.

PLANETARY GEAR CONTROLS

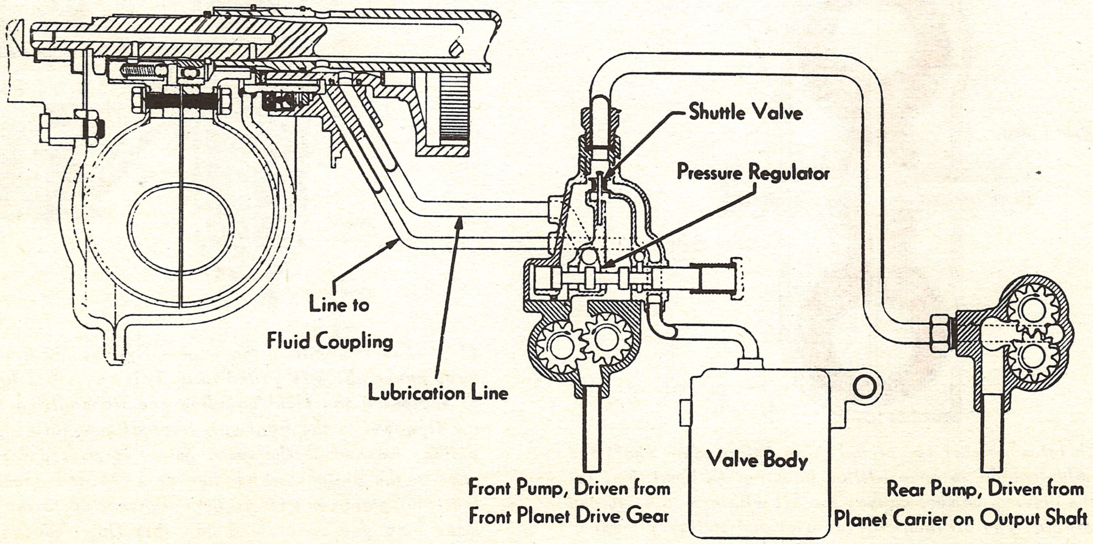
As the planetary gear bands are operated hydraulically an oil pump is required to furnish the pressure. The Hydra-Matic has two oil pumps; one driven by the engine and another driven by the car from the driveshaft. See Fig. 44-7. These pumps maintain pressure to circulate the oil through the fluid flywheel and to the hydraulic operating cylinders known as "Servos." See Fig. 44-8. As the pressures must be maintained within low and high limits a pressure regulating valve is connected into the oil line near the pump. See Fig. 44-7.

We will also need a manually operated valve in the main pressure line to turn the oil under pressure off and on as desired. See Fig. 44-9. Further, we will need valves to direct the oil under pressure to the servo units we wish to use. See Fig. 44-10.

Rather than operate all these control valves manually we can operate the valves hydraulically and automatically by using a governor to operate still other valves. In other words centrifugal force generated by rotational speed will operate a valve which will steer hydraulic pressure to operate another valve hydraulically which will steer the oil pressure to the servo cylinder. See Figs. 44-11 and 44-12. We can thus operate as many bands and servos as we wish by using a valve for each one and applying enough automatic control elements.

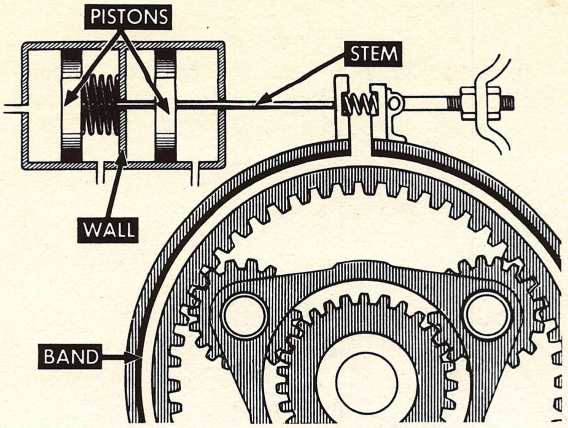
DRIVER CONTROL

Obviously however the matter of gear selection and shifting cannot be left entirely to a mechanical governor, but must always be under the control of the driver. Traffic conditions are such that car speed is not always the desired method of choosing the gear reduction to be used. The driver expresses his needs or desires through the amount of pressure he applies to the foot accelerator which is connected into the system in such a way as to regulate the pressures exerted on the various valves.

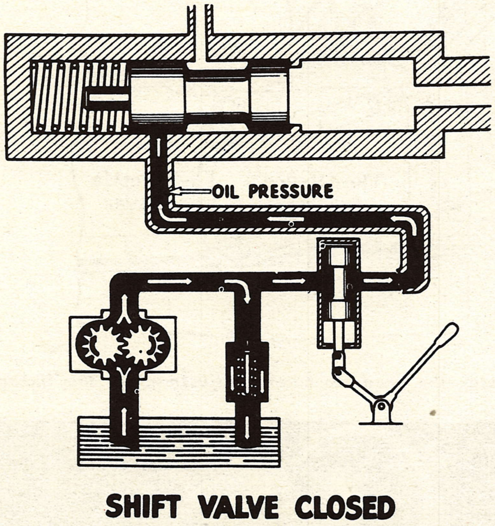

Shuttle Valve
Pressure Regulator
Line to Fluid Coupling
Lubrication Line
Valve Body
Front Pump, Driven from Front Planet Drive Gear
Rear Pump, Driven from Planet Carrier on Output Shaft

44-7. Operation of front and rear transmission oil pumps. Also see text under Dual Range Hydra-Matic for later pump.

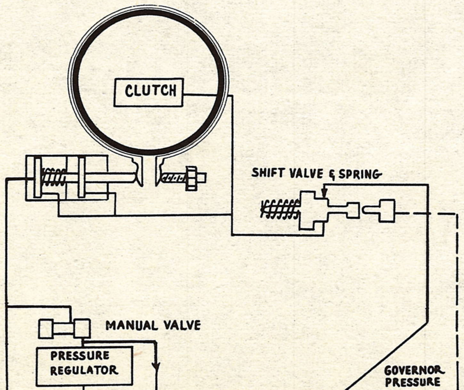
This is done by linking the ~~foot~~ accelerator to a throttle valve in the transmission. This valve is regulated so that the throttle valve pressure is variable depending on how far the throttle is opened. If the throttle is opened lightly, the oil pressure on the shift valves will be low. Oil pressures from the governor will then open the shift valves at a low car speed and the shift will occur at low speed. If the throttle is opened wide, greater car speed will be required to build up governor pressure and the transmission will shift at higher car speed. See Fig. 44-13.


PISTONS
STEM
WALL
BAND

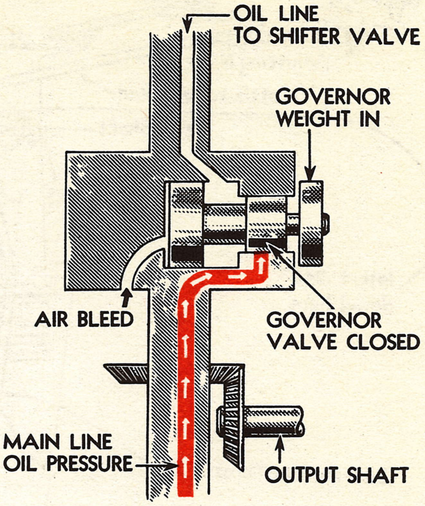
44-8. Method of using hydraulic cylinder and pistons to apply and release band on planetary gear drum.


OIL PRESSURE
SHIFT VALVE CLOSED

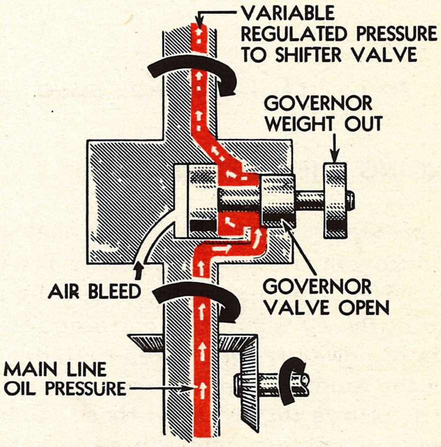
44-9. The control lever of the manual valve corresponds to the gear selector lever on the steering column of the automobile.


CLUTCH
SHIFT VALVE & SPRING
MANUAL VALVE
PRESSURE REGULATOR
OIL PUMP
SUMP
MAIN LINE
GOVERNOR PRESSURE
GOVERNOR

44-10. Method of regulating pressure applied to band on drum.

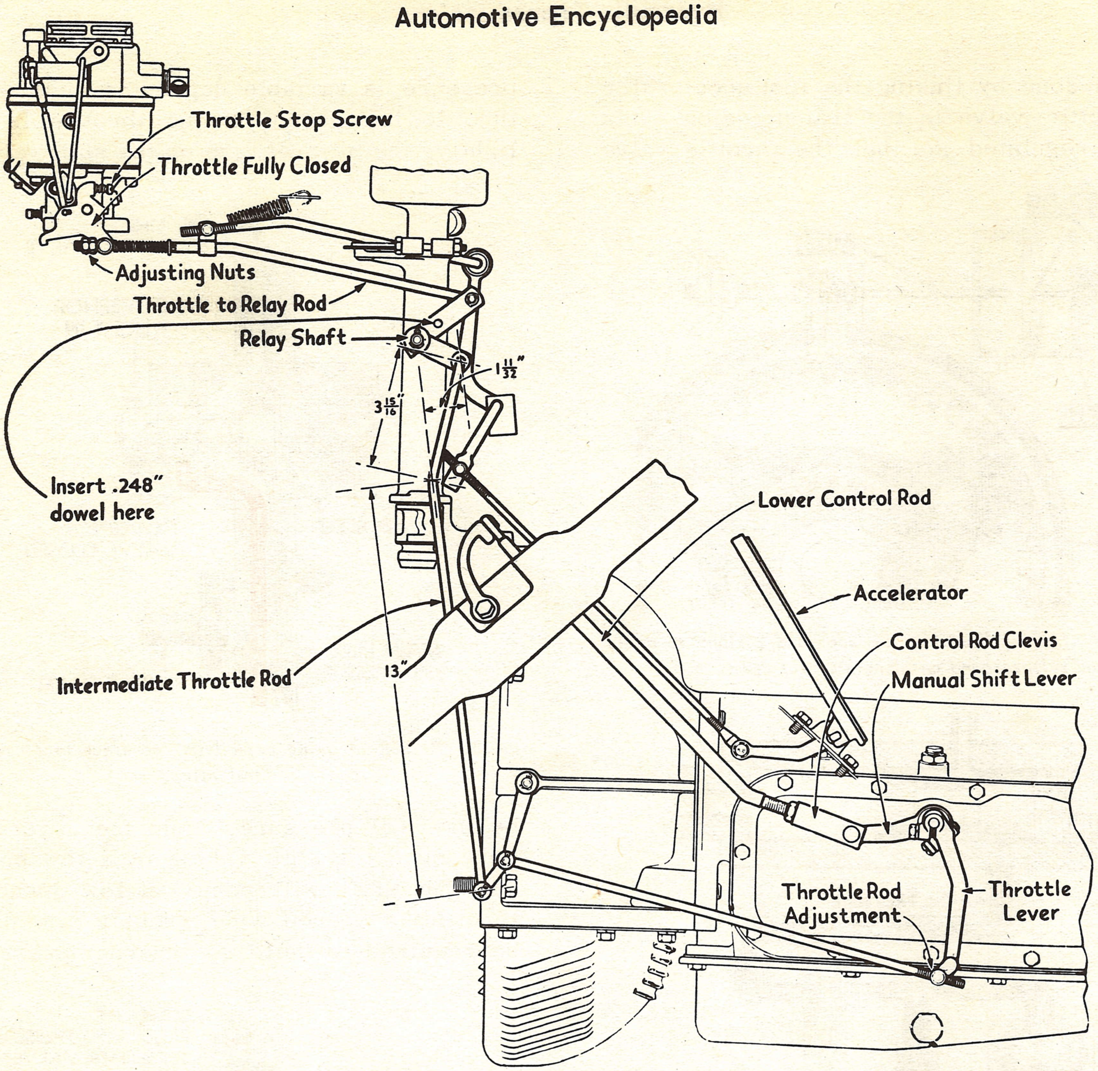

OIL LINE TO SHIFTER VALVE
GOVERNOR WEIGHT IN
AIR BLEED
GOVERNOR VALVE CLOSED
MAIN LINE OIL PRESSURE
OUTPUT SHAFT

44-11. Method of using centrifugal governor to close oil control valve.


VARIABLE REGULATED PRESSURE TO SHIFTER VALVE
GOVERNOR WEIGHT OUT
AIR BLEED
GOVERNOR VALVE OPEN
MAIN LINE OIL PRESSURE

44-12. Valve is shown here in open position.

It will thus be seen that the control system operates on a balanced pressure plan. Springs and varying pressures and speeds are balanced one against the other until a very sensitive and responsive control is obtained over the transmission mechanism. These varying pressures are obtained with springs of different size, length and strength and can be further varied by screw adjustments.


Throttle Stop Screw
Throttle Fully Closed
Adjusting Nuts
Throttle to Relay Rod
Relay Shaft
1 11/32"
3 15/16"
Insert .248" dowel here
Lower Control Rod
Accelerator
Control Rod Clevis
Manual Shift Lever
Intermediate Throttle Rod
13"
Throttle Rod Adjustment
Throttle Lever

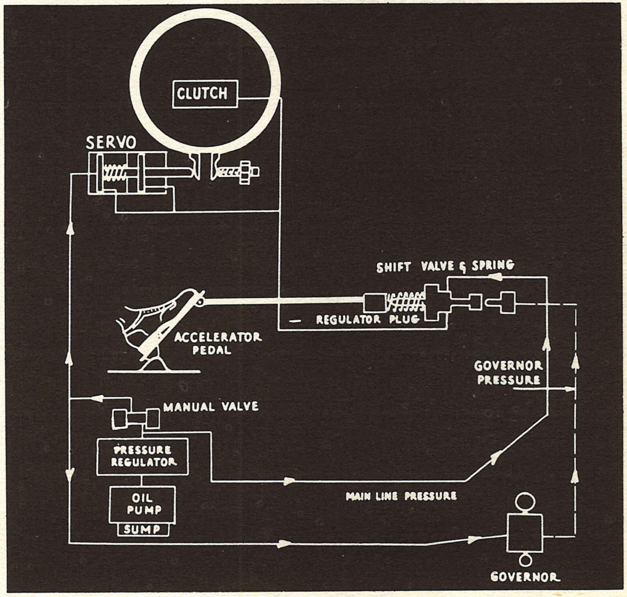
44-13. The typical hook-up of throttle control rods illustrated here indicates the need for careful adjustment of the linkage.

BALANCING THE FORCES

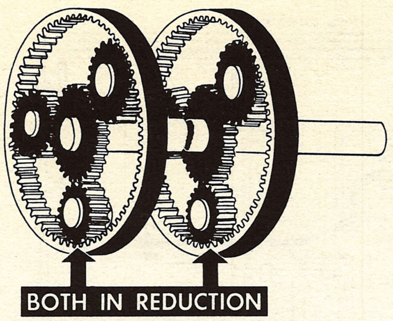
In a previous chapter we found that we could obtain different amounts of power from a hydraulic cylinder at a given pressure by altering the size of the cylinder. We can also get varying amounts of power from a given cylinder size by varying the amount of pressure.

Now it follows that with all these variables at hand we can balance our forces to get various results. For example we can put a spring on one end of a piston in a hydraulic cylinder and regulate the pressure by means of a screw adjustment. On the other side of the piston we can place oil under pressure. Now if the oil pressure is less than the spring pressure the piston will go in one direction. If we increase the speed of the pump to increase the oil pressure we can start the piston moving the other way and can balance the pressure to hold the piston at any point.

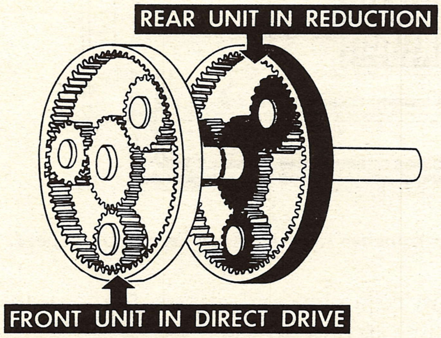
We can also combine a spring and a small piston in one end of the double cylinder and


CLUTCH
SERVO
SHIFT VALVE & SPRING
REGULATOR PLUG
ACCELERATOR PEDAL
GOVERNOR PRESSURE
MANUAL VALVE
PRESSURE REGULATOR
OIL PUMP
SUMP
MAIN LINE PRESSURE
GOVERNOR

44-14. Notice that the linkage from the accelerator pedal applies pressure on the shift valve with governor pressure opposing it. Because this linkage and plug are used to regulate the shift point according to the accelerator position, it is called a regulator plug.


BOTH IN REDUCTION

44-15. In first speed, both the front and rear planetary units are in reduction.

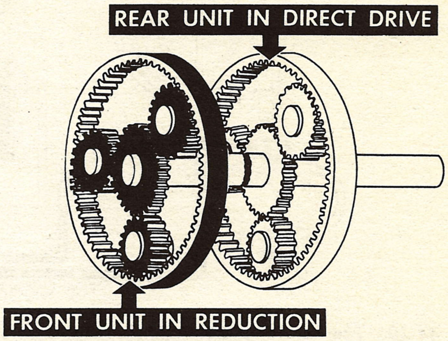

REAR UNIT IN REDUCTION
FRONT UNIT IN DIRECT DRIVE

44-16. In second speed, the front unit is in direct drive and the rear unit is in reduction.

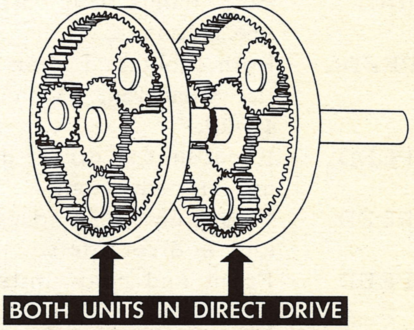
use a larger piston in the other cylinder. And we can place a hydraulic cylinder on each end of a spring and thus change the spring pressure as much as desired. See Fig. 44-14. As the spring pressure increases with the amount it is compressed and the hydraulic pressure varies with the speed of the oil pump, we can obtain almost any series of control variation. By such methods the Hydra-Matic is automatically controlled.

HYDRA-MATIC GEAR SHIFTING

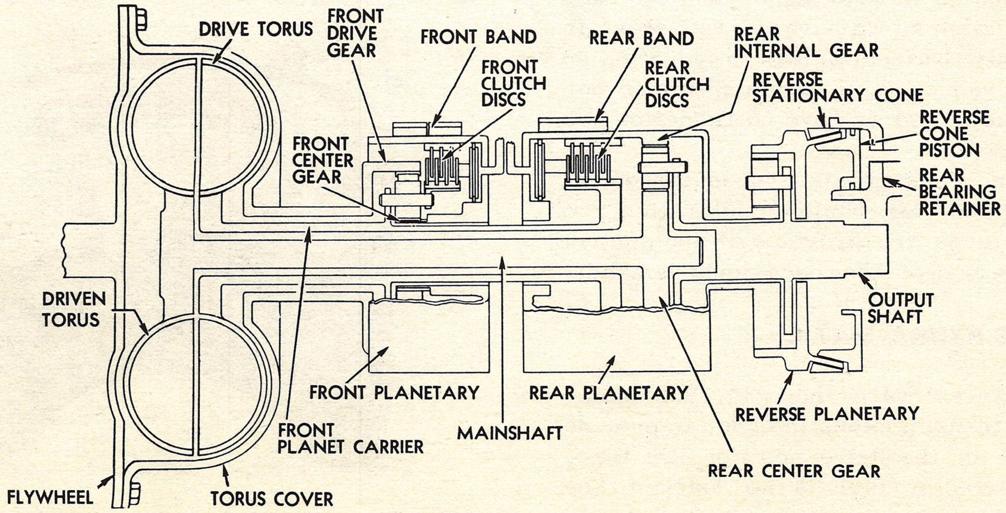
As the planetary gear unit provides only one reduction and one direct drive in the same direction of rotation, it is necessary to use two planetary units connected together in series to obtain four forward speeds. See Figs. 44-15 to 44-19. Both planetary units in the Hydra-Matic are similar but the rear unit is larger than the front unit and provides a greater gear reduction.


REAR UNIT IN DIRECT DRIVE
FRONT UNIT IN REDUCTION

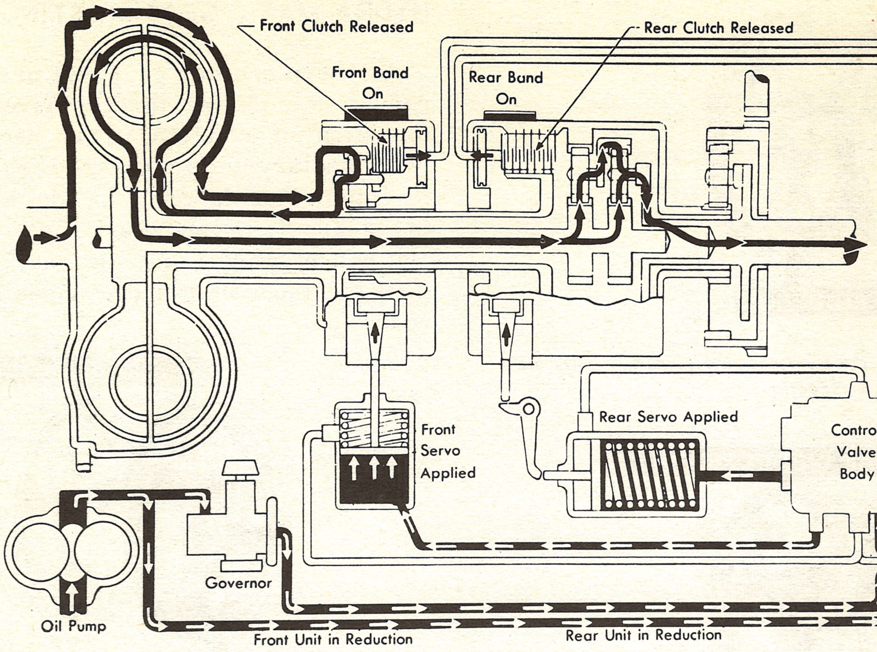
44-17. In third speed, the front unit is in reduction and the rear unit is in direct drive.


BOTH UNITS IN DIRECT DRIVE

44-18. In fourth speed, both units are in direct drive.


DRIVE TORUS
FRONT DRIVE GEAR
FRONT BAND
REAR BAND
REAR INTERNAL GEAR
FRONT CLUTCH DISCS
REAR CLUTCH DISCS
REVERSE STATIONARY CONE
REVERSE CONE PISTON
FRONT CENTER GEAR
REAR BEARING RETAINER
OUTPUT SHAFT
DRIVEN TORUS
FRONT PLANETARY
REAR PLANETARY
REVERSE PLANETARY
FRONT PLANET CARRIER
MAINSHAFT
REAR CENTER GEAR
FLYWHEEL
TORUS COVER

44-19. Arrangement of bands, clutches and gears.


Front Clutch Released
Rear Clutch Released
Front Band On
Rear Band On
Front Servo Applied
Rear Servo Applied
Control Valve Body
Governor
Oil Pump
Front Unit in Reduction
Rear Unit in Reduction

44-20. The flow of power from the engine through the transmission to the propeller shaft is shown here in first speed.

The method used to obtain four forward speeds is as follows:

NEUTRAL	- Both bands and both clutches are released.
1ST SPEED	- Both front and rear units are in reduction. Also see Fig. 44-20.
2ND SPEED	- Front unit in direct drive; rear unit in reduction.
3RD SPEED	- Front unit in reduction; rear unit in direct drive.
4TH SPEED	- Front and rear units in direct drive.

In first speed the front unit supplies 40% gear reduction and the rear unit 60% so we have 100% reduction. In second speed only the rear unit is in reduction so we have 60% reduction. In third speed only the front unit is in reduction so we have 40% reduction. In fourth speed neither unit is in reduction so we have no reduction; we have direct drive.

Driving conditions create a need for downshifting at times for rapid acceleration, so additional features are provided in the control system to take care of these occasional demands.

DUAL RANGE HYDRA-MATIC

Certain changes were made in 1952 model Hydra-Matic transmissions in order to provide a dual range in the drive position. On these models the selector dial is so marked. See Fig. 44-21. The 1952 alterations did not change the fundamentals of the transmission. Some new parts were added and minor changes in service procedure are entailed.

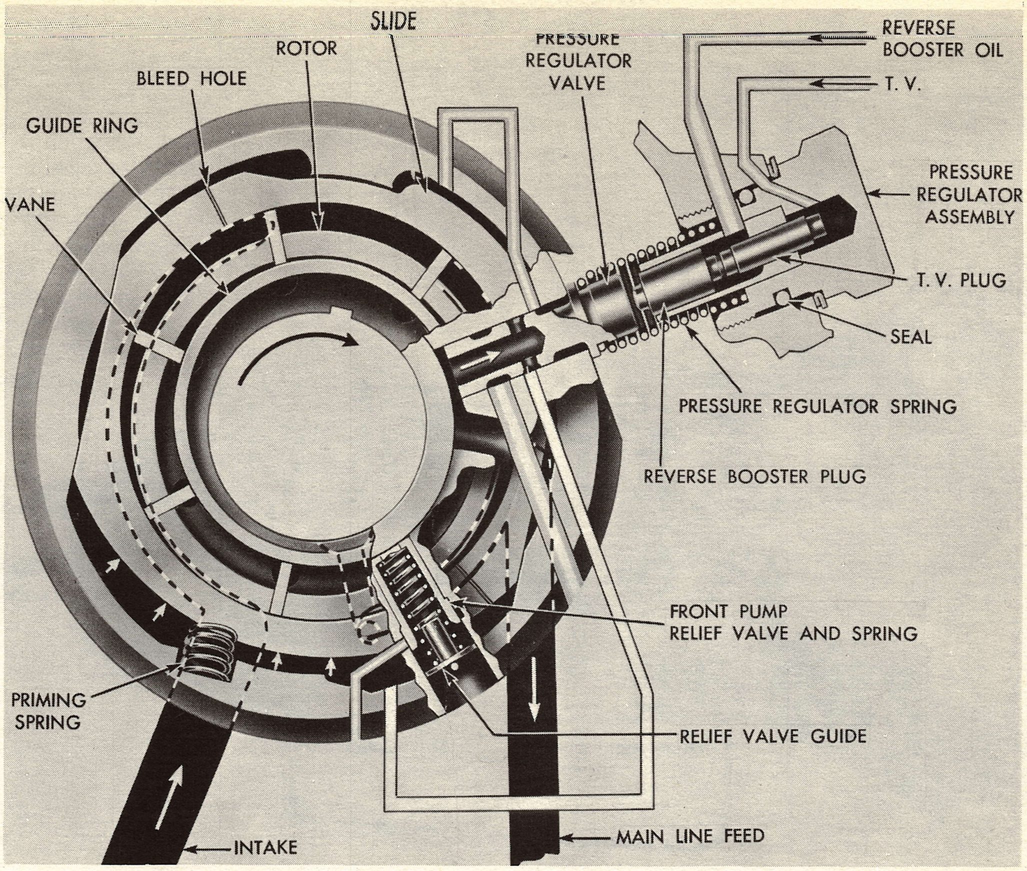
One of the new parts is an improved front pump which regulates its output to the requirements of the transmission hydraulic system. The pump is of the vane type with a moving slide. See Fig. 44-22 and 44-23.

The output of the pump is determined by the position of the slide. When the slide is up, the pump delivers maximum output; when the slide is centered the output is zero; when the slide is down the pump acts as a relief valve for excessive rear pump output.

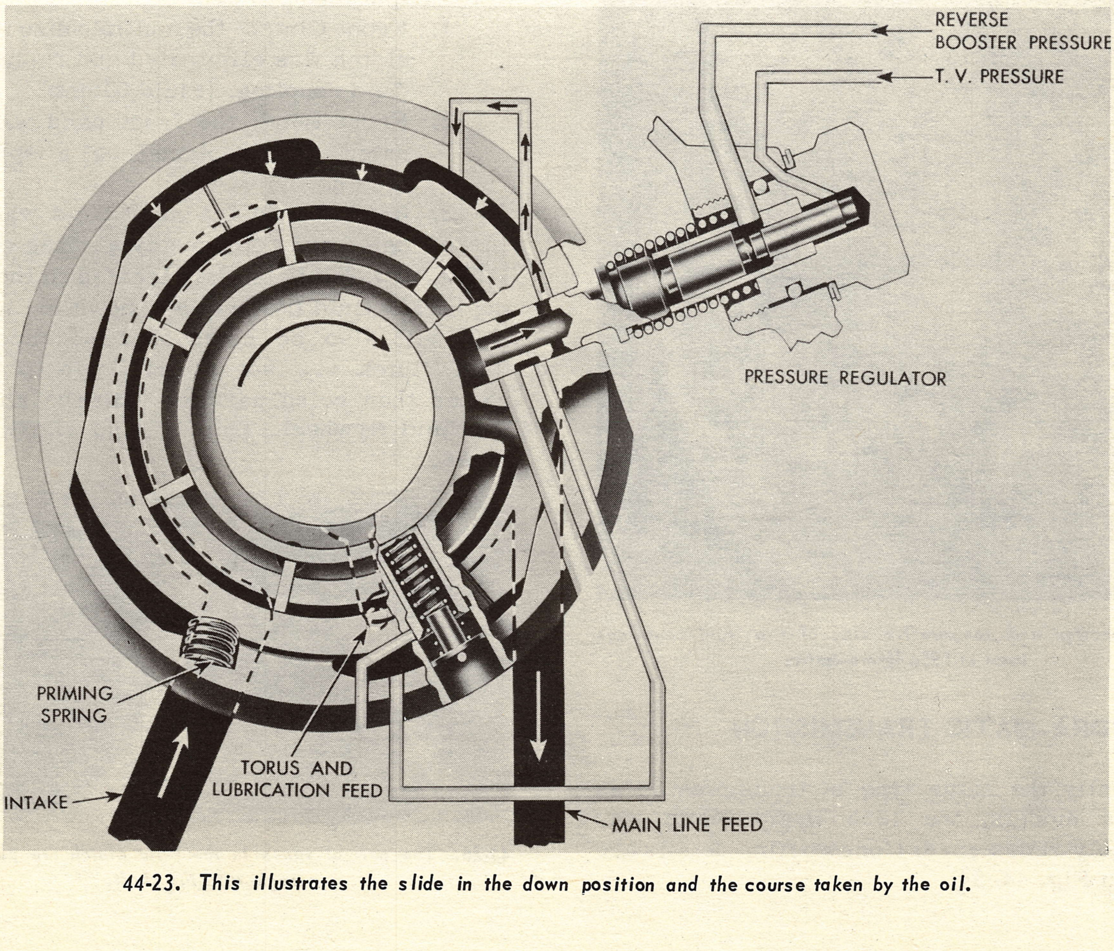
Minor changes were made in the hydraulic circuit such as valves and controls to adapt it to the needs of the dual range construction.

N
DR
Lo
R
Dual Range
Hydra-matic Drive

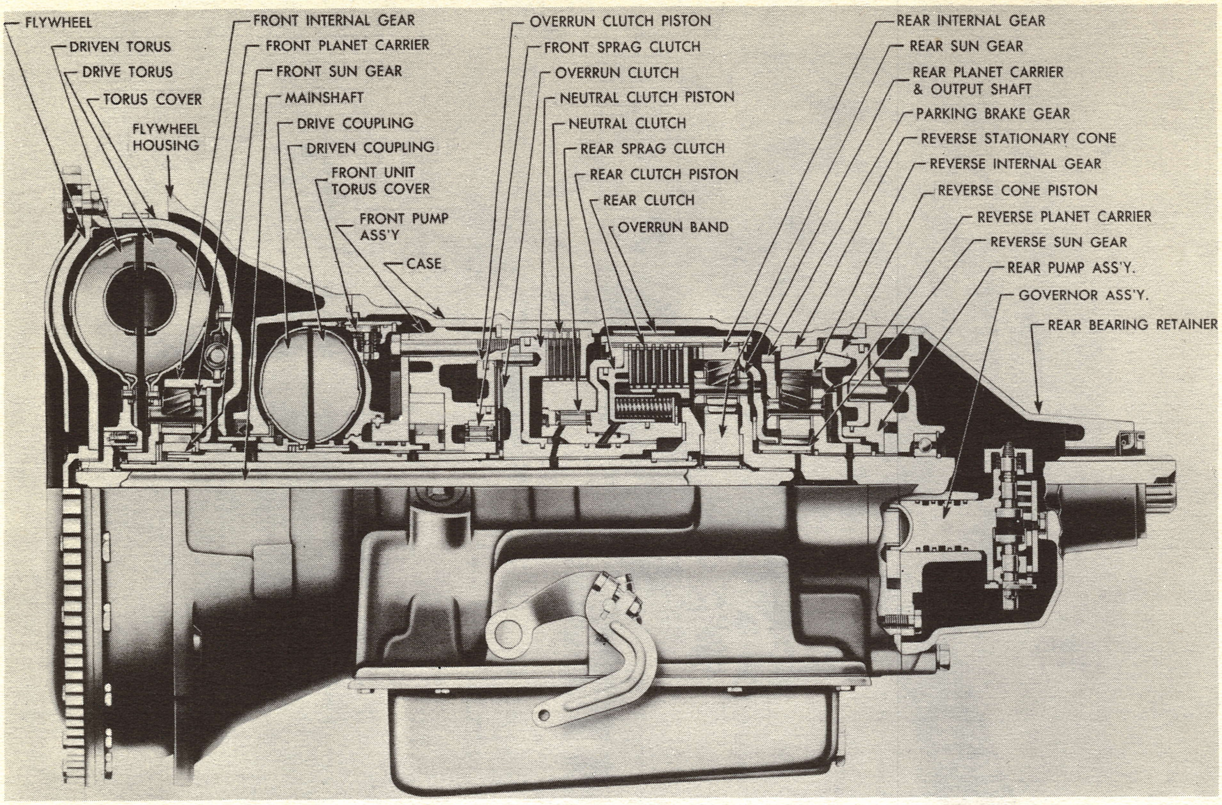
44-21. Two positions in the drive range are provided on the dual range Hydra-Matic selector.


SLIDE
ROTOR
PRESSURE REGULATOR VALVE
REVERSE BOOSTER OIL
T. V.
BLEED HOLE
GUIDE RING
PRESSURE REGULATOR ASSEMBLY
VANE
T. V. PLUG
SEAL
PRESSURE REGULATOR SPRING
REVERSE BOOSTER PLUG
FRONT PUMP RELIEF VALVE AND SPRING
PRIMING SPRING
RELIEF VALVE GUIDE
MAIN LINE FEED
INTAKE

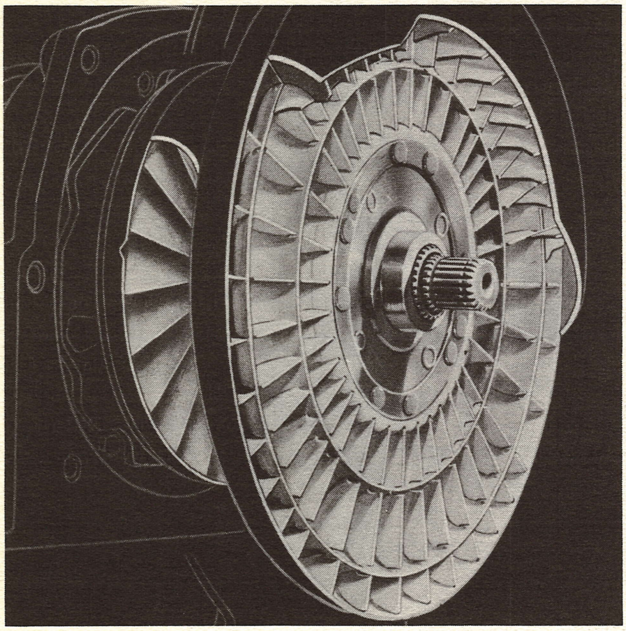
44-22. *Cross-section of later Hydra-Matic pump showing installation of pressure regulator assembly.*


REVERSE BOOSTER PRESSURE
T. V. PRESSURE
PRESSURE REGULATOR
PRIMING SPRING
TORUS AND LUBRICATION FEED
INTAKE
MAIN LINE FEED

44-23. *This illustrates the slide in the down position and the course taken by the oil.*


FLYWHEEL
DRIVEN TORUS
DRIVE TORUS
TORUS COVER
FLYWHEEL HOUSING
FRONT INTERNAL GEAR
FRONT PLANET CARRIER
FRONT SUN GEAR
MAINSHAFT
DRIVE COUPLING
DRIVEN COUPLING
FRONT UNIT TORUS COVER
FRONT PUMP ASS'Y
CASE
OVERRUN CLUTCH PISTON
FRONT SPRAG CLUTCH
OVERRUN CLUTCH
NEUTRAL CLUTCH PISTON
NEUTRAL CLUTCH
REAR SPRAG CLUTCH
REAR CLUTCH PISTON
REAR CLUTCH
OVERRUN BAND
REAR INTERNAL GEAR
REAR SUN GEAR
REAR PLANET CARRIER & OUTPUT SHAFT
PARKING BRAKE GEAR
REVERSE STATIONARY CONE
REVERSE INTERNAL GEAR
REVERSE CONE PISTON
REVERSE PLANET CARRIER
REVERSE SUN GEAR
REAR PUMP ASS'Y.
GOVERNOR ASS'Y.
REAR BEARING RETAINER

44-24. Construction details of Pontiac Strato-Flight Hydra-Matic.



44-25. Location and comparative size of two fluid couplings used in 1956 Hydra-Matic.

1956 HYDRA-MATIC TRANSMISSION

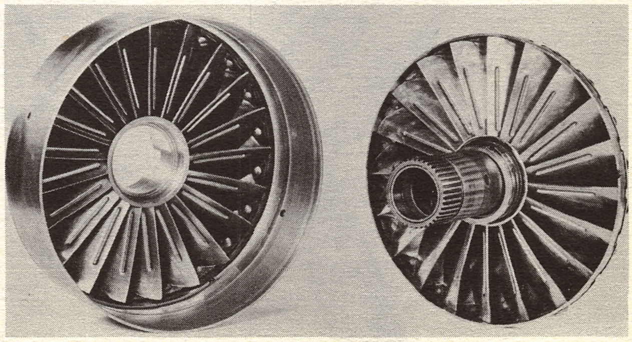
Basically the same type of transmission as previous models, the 1956 Hydra-Matic was completely redesigned. Construction details are shown in Fig. 44-24.

Principal changes are:

1. Front Clutch; the multiple disc type front clutch was eliminated and replaced by a fluid coupling. (Fluid Clutch)
2. Front Band; the front band was eliminated and replaced by a sprag type clutch.
3. Rear Band; the rear band was eliminated and replaced by a sprag clutch.

The new fluid clutch is located to the rear of the larger fluid flywheel as shown in Fig. 44-25.

It will also be noted that the vanes of the fluid clutch are set at an angle to the shaft rather than being parallel with the shaft as in the fluid flywheel. This is also shown in Fig. 44-26.

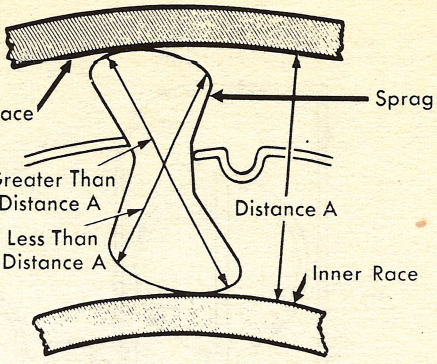


44-26. The pair of vanes in the fluid clutch are placed at an angle with the shaft.

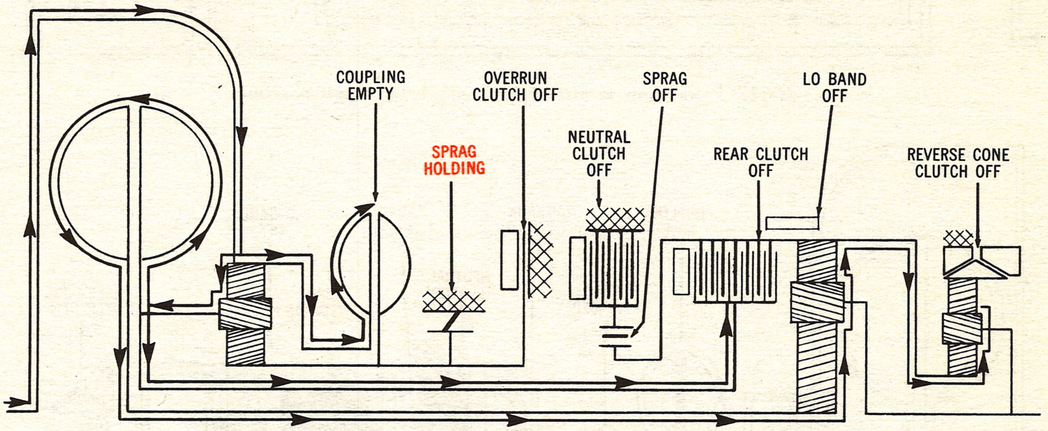
By providing a rapid method of filling and emptying this fluid clutch, it is possible to have a complete release of power application or a positive connection rapidly and smoothly.

The sprag clutch operates in much the same manner as the roller and ramp type of free-wheel device, but uses special shape sprag segments instead of rollers. See Fig. 44-27.

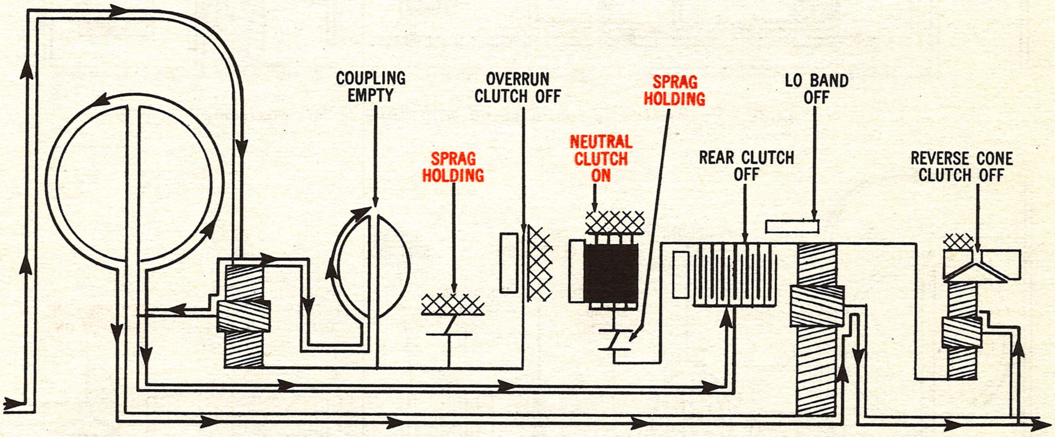
For all normal driving, the selector is placed in the left position of the DR range. The power flow through the transmission in the left


Outer Race
Sprag
Greater Than Distance A
Less Than Distance A
Distance A
Inner Race

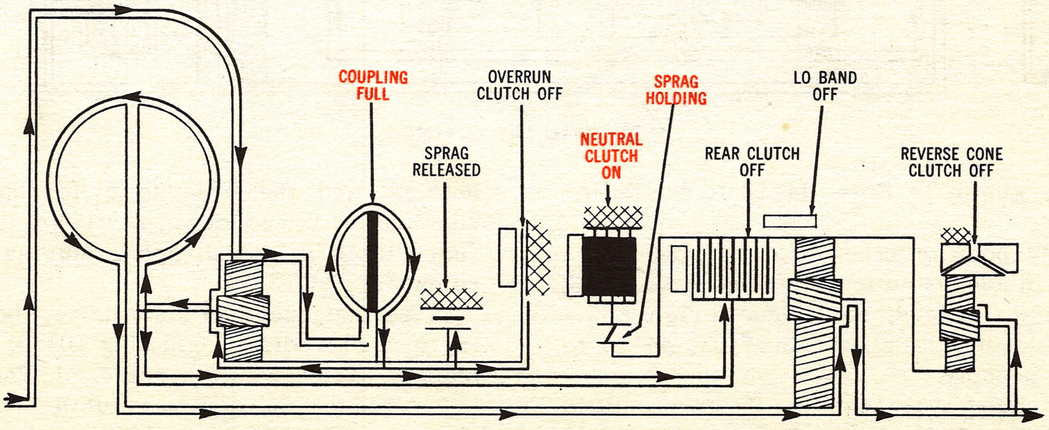
44-27. The action of the sprag segments is shown here. The action allows rotation in one direction but not in the other.


COUPLING EMPTY
OVERRUN CLUTCH OFF
SPRAG OFF
LO BAND OFF
SPRAG HOLDING
NEUTRAL CLUTCH OFF
REAR CLUTCH OFF
REVERSE CONE CLUTCH OFF

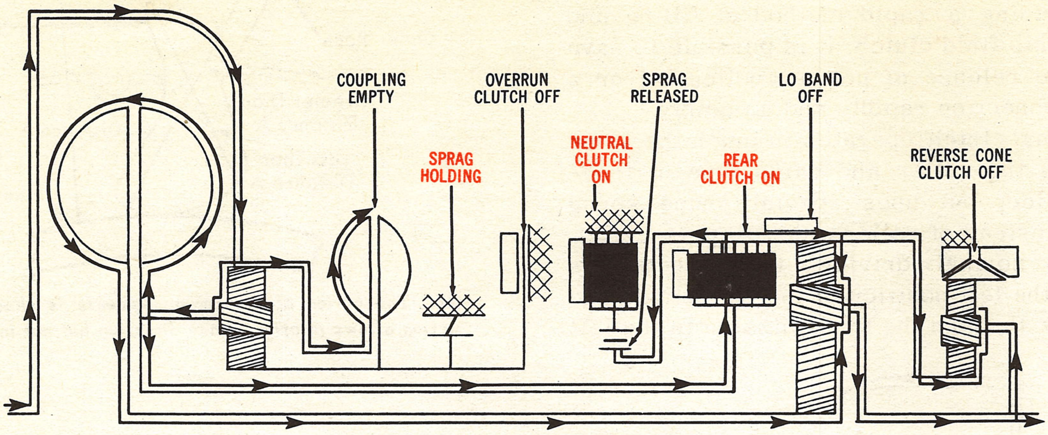
44-28. Power flow in neutral with engine running.


COUPLING EMPTY
OVERRUN CLUTCH OFF
SPRAG HOLDING
LO BAND OFF
SPRAG HOLDING
NEUTRAL CLUTCH ON
REAR CLUTCH OFF
REVERSE CONE CLUTCH OFF

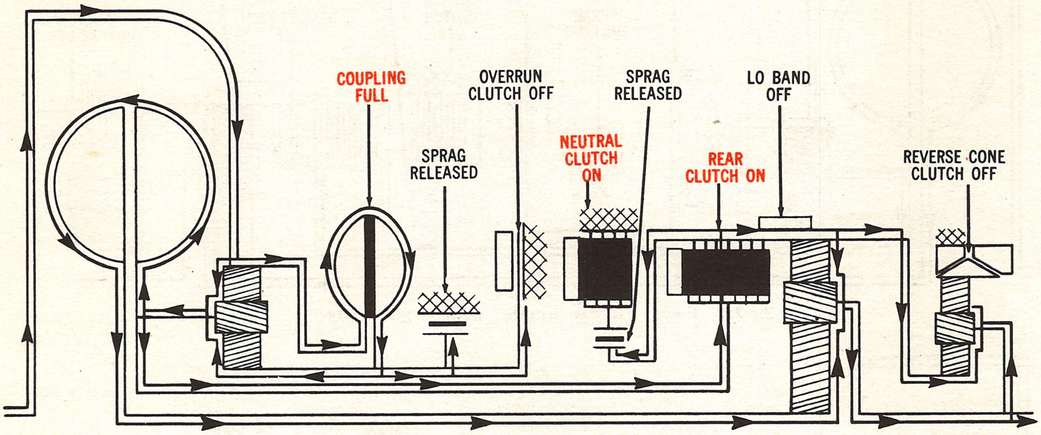
44-29. Power flow in first speed with drive in left position.


COUPLING FULL
OVERRUN CLUTCH OFF
SPRAG HOLDING
LO BAND OFF
SPRAG RELEASED
NEUTRAL CLUTCH ON
REAR CLUTCH OFF
REVERSE CONE CLUTCH OFF

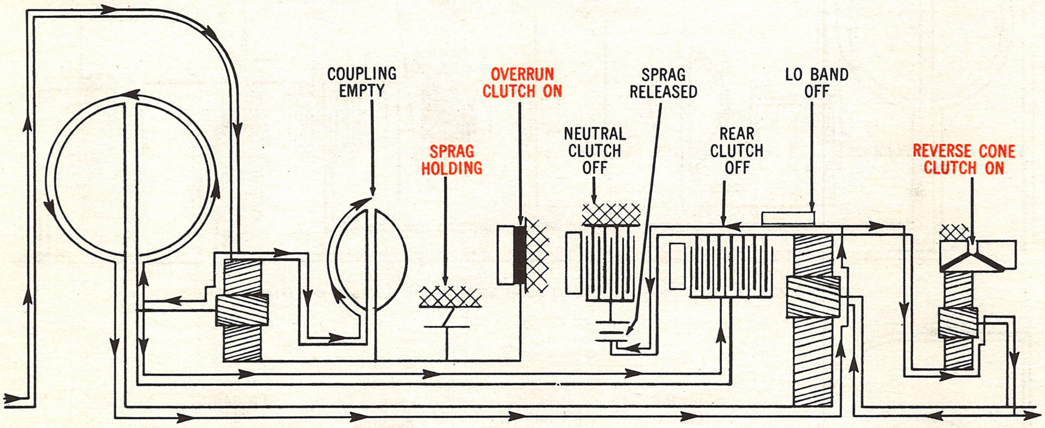
44-30. Power flow in second speed with drive in left position.


COUPLING EMPTY
OVERRUN CLUTCH OFF
SPRAG RELEASED
LO BAND OFF
SPRAG HOLDING
NEUTRAL CLUTCH ON
REAR CLUTCH ON
REVERSE CONE CLUTCH OFF

44-31. *Power flow in third speed with drive in left position.*


COUPLING FULL
OVERRUN CLUTCH OFF
SPRAG RELEASED
LO BAND OFF
SPRAG RELEASED
NEUTRAL CLUTCH ON
REAR CLUTCH ON
REVERSE CONE CLUTCH OFF

44-32. *Power flow in fourth speed with drive in left position.*


COUPLING EMPTY
OVERRUN CLUTCH ON
SPRAG RELEASED
LO BAND OFF
SPRAG HOLDING
NEUTRAL CLUTCH OFF
REAR CLUTCH OFF
REVERSE CONE CLUTCH ON

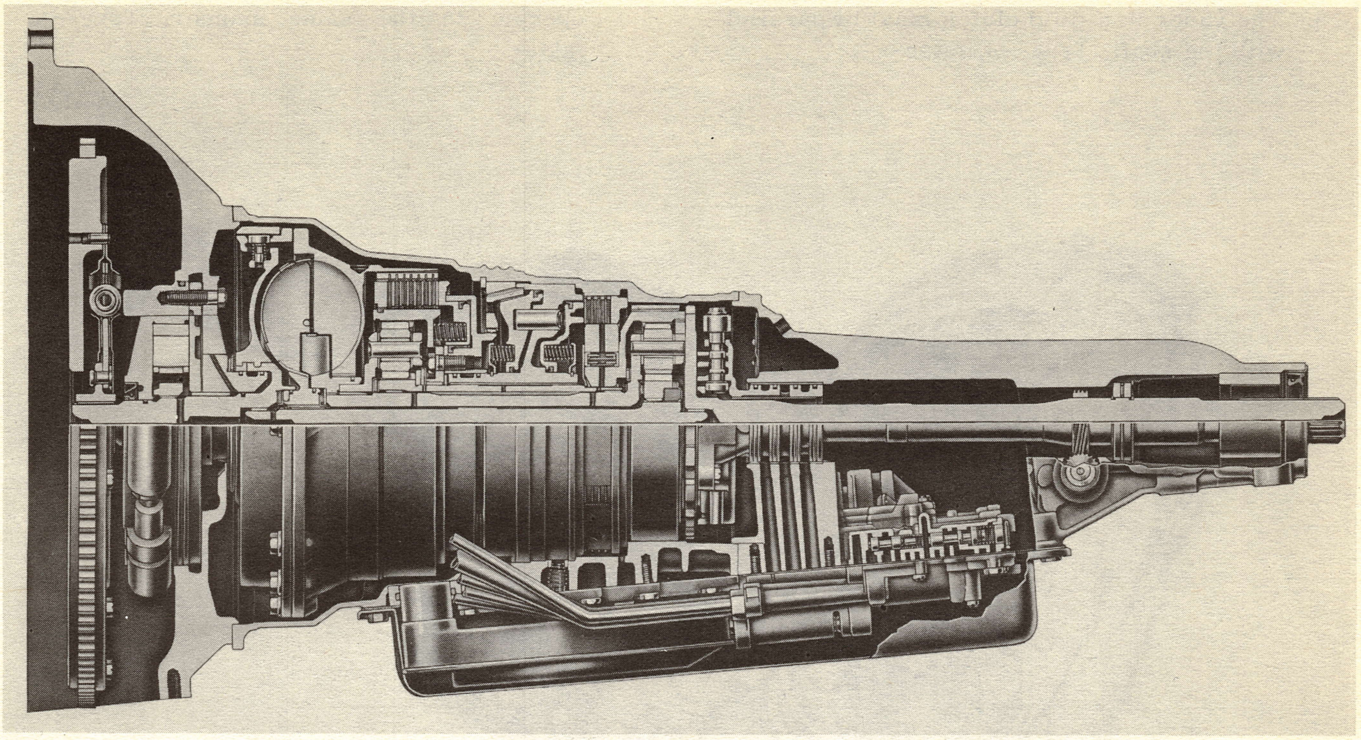
44-33. *Power flow in reverse.*

position is shown in Figs. 44-28 to 44-33, inclusive.

The right position is used for improved performance in congested traffic, when descending long mountain grades, etc. When in right position, the conditions shown in Figs. 44-28 to 44-33 do not apply.

In first speed of right drive, the front unit is in reduction with the coupling empty, the sprag holding, and the overrun clutch applied. The rear unit is in reduction, neutral clutch applied, rear clutch released, sprag holding, low band released.

In second speed of right drive, the front unit is in direct drive, coupling filled, sprag released, overrun clutch released. The rear unit is in reduction, neutral clutch applied, rear clutch released, sprag holding, low band re-



44-34. The addition of a reactor between the two members of a fluid coupling, as shown here on the 1961 Pontiac, provides some characteristics of a torque converter.

leased.

In third speed of right drive, the front unit is in reduction, coupling empty, sprag holding, overrun clutch applied. The rear unit in direct drive, neutral clutch applied, rear clutch applied, sprag released, low band released.

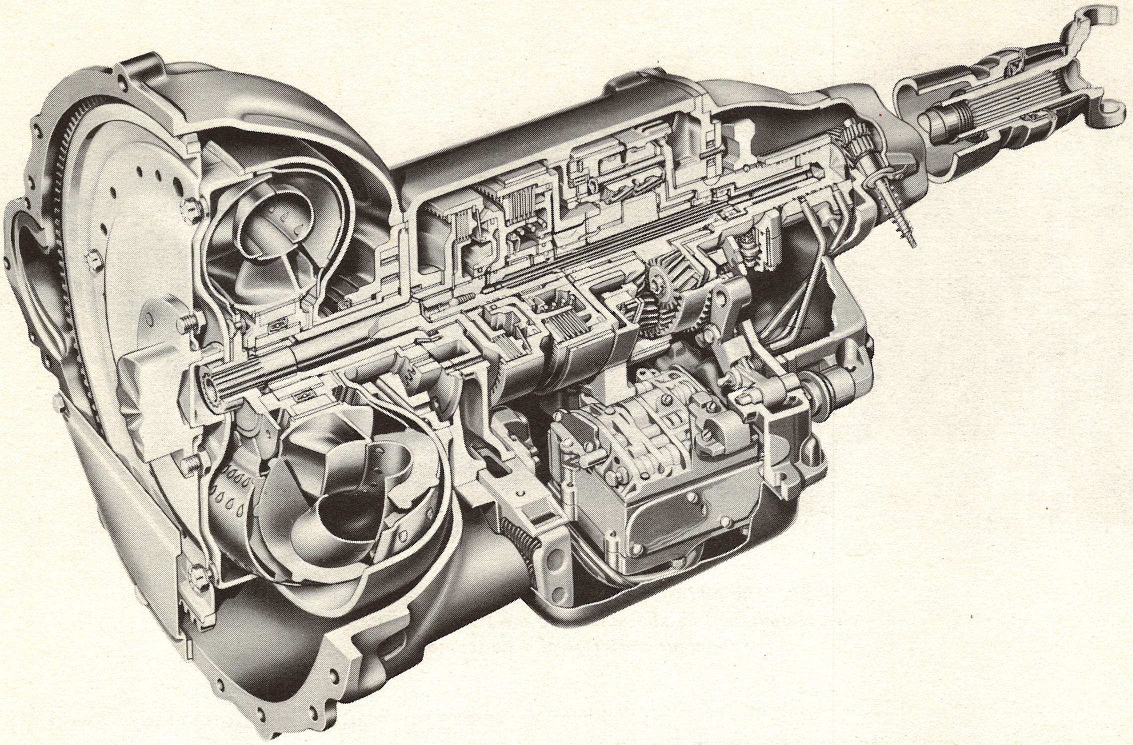
QUIZ - HYDRAULIC TRANSMISSIONS

1. Name the four elements of a hydraulic automatic transmission.
2. Check each of the following which can be used singly or in combination to control hydraulic automatic transmissions.
   - Hand levers---
   - Engine vacuum---
   - Engine size---
   - Foot pedals---
   - Engine oil pressure---
   - Engine water temperature---
   - Electricity---
   - Car speed---
   - Car weight---
   - Engine speed---
   - Engine compression---
   - Hydraulic pressure---
3. The hydraulic fluid is sealed in the fluid flywheel of the Hydra-Matic. True---, false---.
4. How is car "creeping" diminished in the Hydra-Matic?
5. The Hydra-Matic has an oil pump driven by: the engine---, the car---, both---.
6. Hydraulic pistons and steel springs can be combined on a single valve to provide a balance of forces. True---, false---.
7. In fourth speed, which planetary units of the Hydra-Matic are in reduction? Front unit---, rear unit---, neither unit---, both units---.
8. Can more than one fluid coupling be used in a single transmission? Yes---, no---.
9. Can more than one free-wheel clutch be used in a single transmission? Yes---, no ---.
10. How can a fluid coupling be constructed that will have some characteristics of both the fluid flywheel and the torque converter?
11. Can the capacity of an oil pump be altered while in operation by means other than the speed of pump rotation? Yes---, no---.
12. In fourth speed, the rear panetary unit of the Hydra-Matic provides a gear reduction

of: 0%---, 40%---, 60%---.

13. The vanes in a fluid clutch must be parallel with the shaft. True---, false---.

14. A sprag clutch and a free-wheel device operate in the same manner. True---, false---.



Ford Galaxie automatic dual range transmission.

TORQUE CONVERTERS

Torque converters of the hydraulic type for automobiles have an outward appearance and some similarity to fluid flywheels, which we have already studied. The operation of the units is NOT the same. The conventional fluid flywheel simply transmits the same amount of torque that is applied to it, while a torque converter increases the amount of torque applied to it. This torque increase is accomplished hydraulically within the unit itself. See Fig. 45-1.

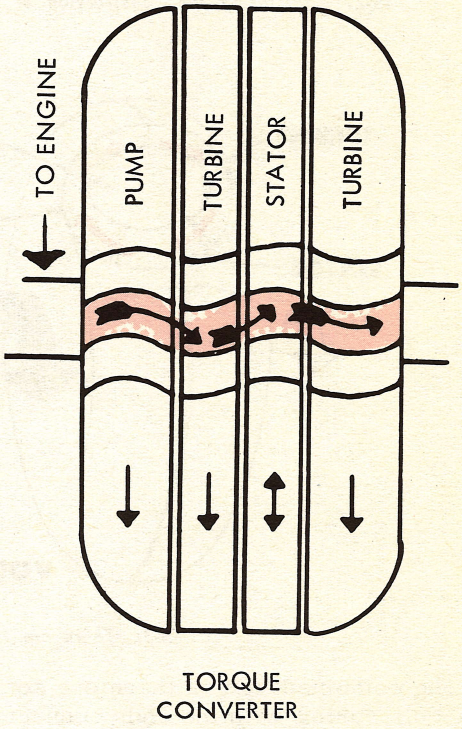
There are many kinds of torque converters, but we shall consider herein only those types currently used in passenger automobiles. Actually a sliding gear transmission is a mechanical torque converter and so is an electric drive an electrical torque converter. We are now concerned only with the hydraulic type wherein a fluid is used as the medium for torque conversion.

METHOD OF OPERATION

In the following we shall take up the details of construction and operation of hydraulic torque converters. First however we shall consider the basic principle upon which all of them operate. They all use the engine to drive a pump which impells the fluid against the vanes of a turbine or turbines connected to the driveshaft of the automobile.

Now it may be difficult to imagine squirting a stream of oil against a blade with enough force to drive an automobile. Actually there are many streams of oil acting against many turbine blades simultaneously. And instead of a stream of fluid it is a veritable torrent* of oil at considerable pressure. So much pressure that the full power of the engine is used at times.

From our previous studies of hydraulic pressure we know that the pressure increases as the speed of the pump increases. The pump in this case is driven by the car engine and instead of a single pump outlet each of the vanes on the circular impeller is a pump nozzle. See Fig. 45-2. It will be noticed that the vanes are set at an angle in the torque converter, whereas they are usually parallel to the axis in a fluid flywheel.



45-1. By placing a stator between the first turbine or rotor and a second turbine, fluid leaving first turbine is redirected to second turbine, and torque is thus multiplied. First and second turbines are connected together. The stator can turn in one direction only.

Remembering now how the action of centrifugal force tends to set up a vortex flow of oil around the torus ring in a fluid flywheel and keeping in mind that the angle of the vanes tends

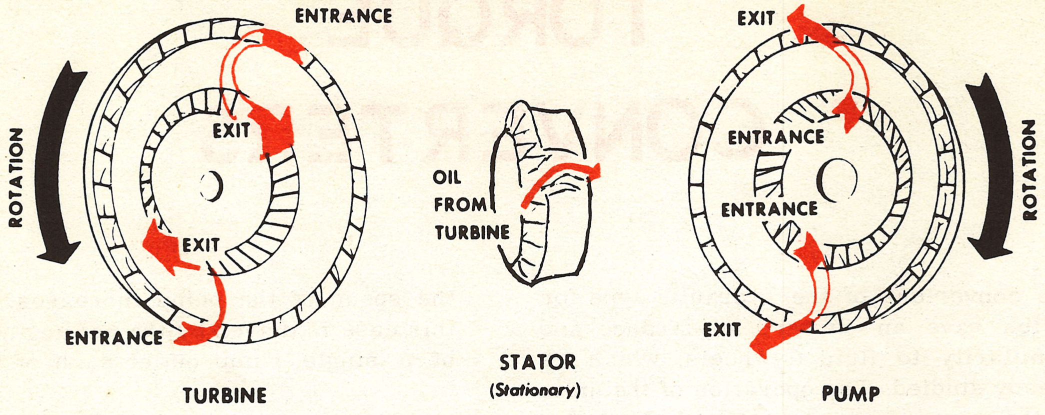
---

**In one current make of torque converter the oil leaves the pump exits at the rate of 63 barrels per minute maximum.*

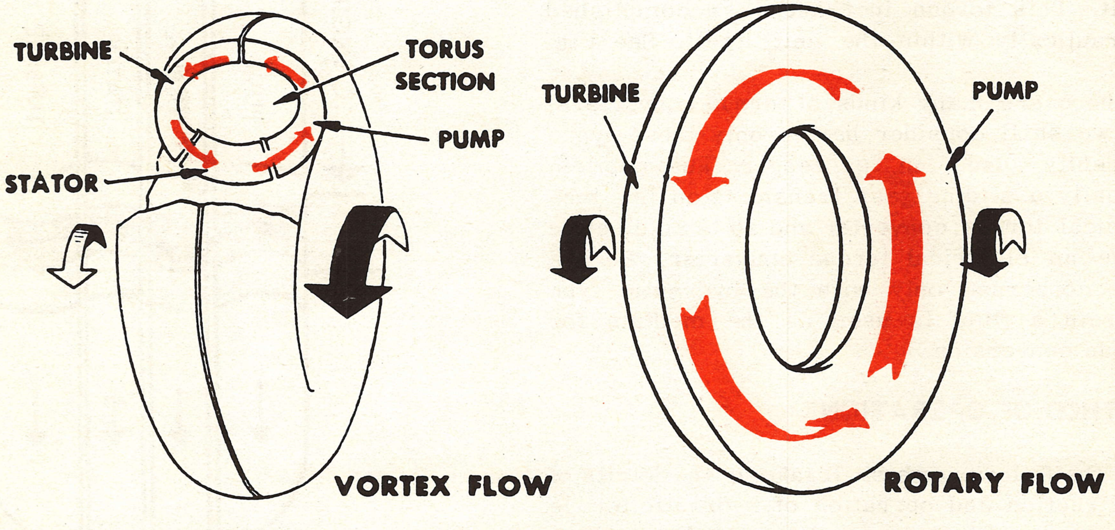
to set up a rotary flow also we have a corkscrew action within the converter. That is, the oil flows in a small circle parallel to the axis and in another larger circle at a right angle to the axis. The combined flow is therefore something like a coil spring with the ends connected. See Figs. 45-3 and 45-4.

The actual path of the oil flow is indicated by the arrows in Fig. 45-2, which also illustrates a second series of vanes nearer the center through which the oil returns to the outer or primary pump after it has gone through this inner or secondary pump.

An actual structure is shown in Fig. 45-5. Fig. 45-6 shows the matching turbine of the unit.


ENTRANCE
EXIT
ROTATION
EXIT
ENTRANCE
TURBINE
OIL
FROM
TURBINE
STATOR
(Stationary)
EXIT
ENTRANCE
ENTRANCE
ROTATION
EXIT
PUMP

45-2. Illustrating the construction of the pump, turbine and stator and the path of the oil circulation through each of them.

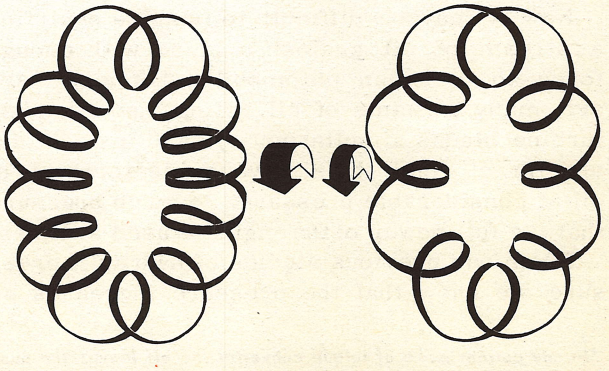

TURBINE
TORUS SECTION
PUMP
STATOR
VORTEX FLOW
TURBINE
PUMP
ROTARY FLOW

45-3. There are two types of oil circulation within the unit.

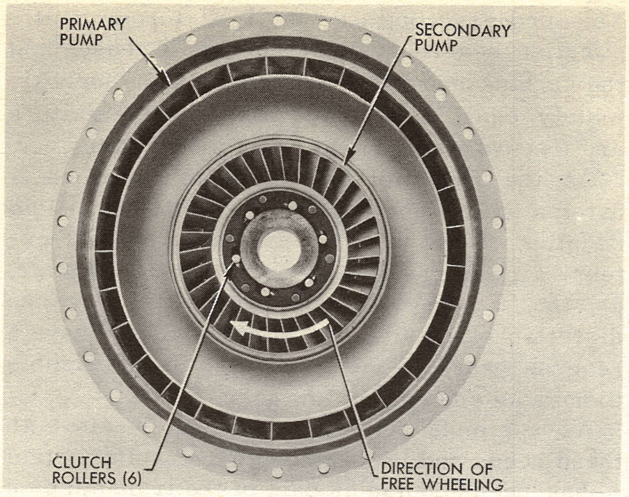
METHOD OF INCREASING TORQUE

The circulation of the oil as just described transmits torque from the pump to the turbine, but does not increase the torque.

Reference to Fig. 45-2 will show that the continuous whirling ring of oil emerges from the twisting passages of the turbine in a direction opposite to the pump rotation. If the oil flow was directed into the pump at this time it would oppose rotation and cause loss of power.

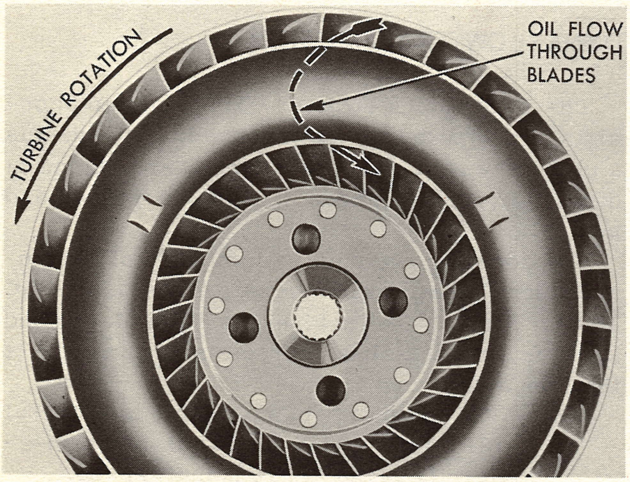


45-4. The two types of oil flow in combination produce a spiral.



45-5. *Location and shape of primary and secondary pumps.*

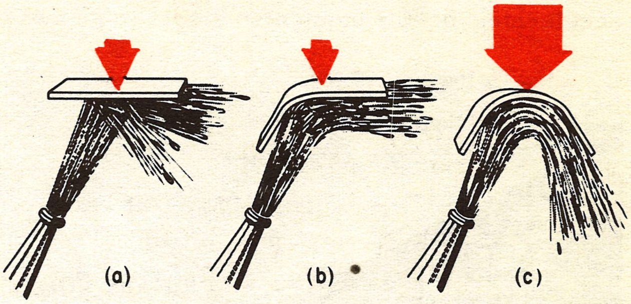
It will be noted that the oil passages at the rim of the turbine where the oil enters must become smaller as they approach the smaller diameter of the secondary turbine. As the same volume of oil must squeeze through these funnel-like passages the oil stream will have a greater velocity when it leaves the turbine than when it leaves the pump. This increased velocity is utilized to increase torque by directing it against a reactor or stator which acts as a fluid lever or fulcrum. See Fig. 45-7.



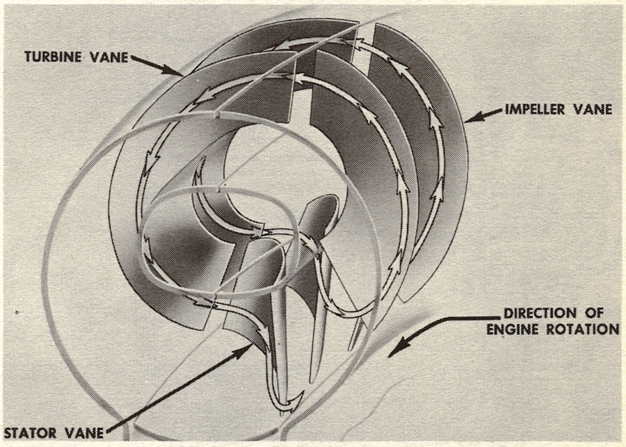
45-6. *The matching turbine for the pump shown in Fig. 45-5.*

This stator is a curved blade which the oil strikes as it leaves the turbine. The curved blade turns the oil into the direction of pump rotation. See Fig. 45-8. Now that the stream of oil is moving in the same direction, but at greater velocity, it enters the pump smoothly. Its velocity is added to that developed in the pump so that the total velocity at the pump exits has been increased. This regenerative action is the key to the torque multiplication process in the hydraulic torque converter.

In order for the reactor or stator to be able to change the direction of oil flow it must be stationary during the process of torque multiplication. However when the pump and turbine are turning at equal speed it would create resistance. Therefore it is mounted on a free-wheel hub so that it can turn in one direction only. One method of mounting is shown in Fig. 45-9. In this case more than one stator is used and both are mounted on free-wheel hubs.



45-7. *A stream of oil aimed at a flat surface as at "a," splashes off at various angles. It can be made to flow more smoothly by curving the entrance as at "b," and can be reversed as at "c" with a resultant increase in force as indicated by the large arrow.*



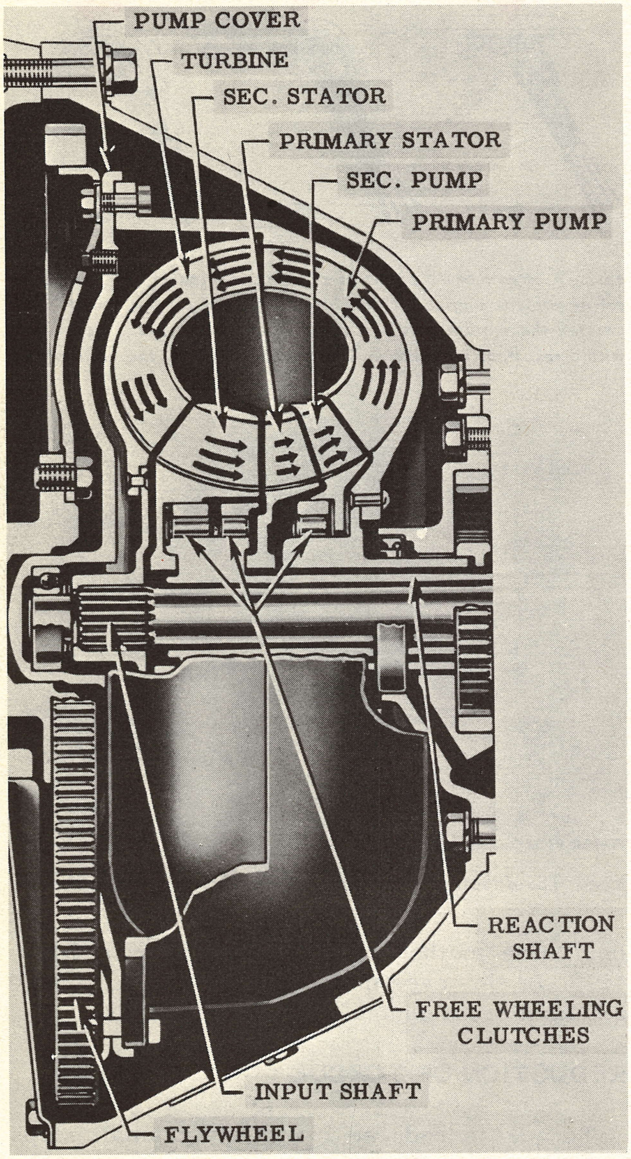
45-8. *The direction of oil flow is reversed by the stator vane.*

REDUCTION OF TORQUE

Torque is reduced in infinitely small steps and automatically according to the needs of the driver just as it was increased. Torque was increased by accelerating the engine speed until the car gets under way. As the car accelerates, the turbine speed increases accordingly which causes the vortex flow of the oil to decrease. At the same time the rotary flow increases. As the turbine speed increases centrifugal forces build up in it just as they do in the pump.

In the turbine however the oil flows toward the center instead of away from the center as in the pump, so the result is to resist the flow of oil going to the stator and pump. The turbine is now going away from the stator and thus reducing the impact of the oil being thrown against the stator vanes. This of course reduces the velocity of the oil entering the pump.

The engine speed also increases as the car accelerates so the pump also starts to go away from the stator which further decreases the oil force on the pump from the stator faster than the oil pump output increases from the higher speed of rotation. The overall effect of these changes is to reduce the vortex flow of the oil and the regenerative action from the stators.



45-9. *Two stators are used in the Buick Dynaflow Torque Converter.*

This process continues until all torque multiplication ceases as the need for it ceases and the turbine and pump are running at approximately equal speed. At this time the stators are free-wheeling along in the oil stream.

As the reduction and increase of torque is automatically accomplished within the fluid coupling it is not necessary to have any extensive gearing in the transmission. However, as the torque converter works in only one direction of rotation, it is necessary to have a reverse gear of some kind. Also it is desirable to have an emergency low gear.

As a simple planetary gear set meets both these needs and lends itself to hydraulic control it has been adopted as part of the transmission system and is mounted in back of the torque converter.

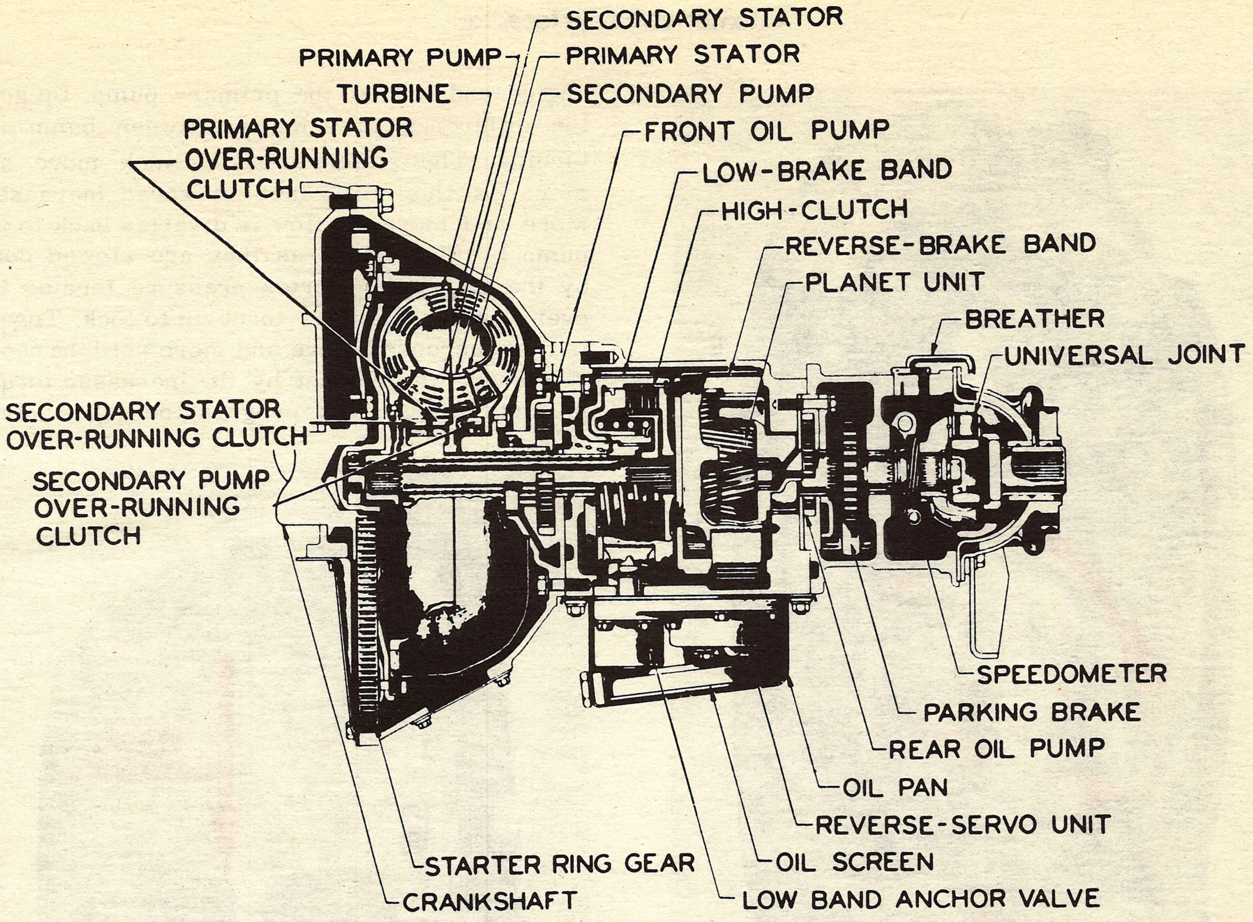
The basic Buick Dynaflow is a typical example of a torque converter type of automatic transmission and will serve our purpose herein. It has been built in several variations which will be illustrated and described. Other makes will be illustrated and described in brief form as the principles of operation apply to all of them in a general way. Specific features will be pointed out.

DYNAFLOW TRANSMISSION

The first Buick Dynaflow Transmission consists of a hydraulic torque converter which, plus a planetary gear set, gives the driver a choice of direct drive, emergency low, reverse and neutral.

The torque converter is composed of five independent rotating members as shown in Fig. 45-10. The Twin Turbine Dynaflow described later in this text has four elements instead of the five listed here.

1 - The primary pump which is integral with the engine flywheel and consequently turns at crankshaft speed.
2 - A secondary pump which can either free-wheel or function with the primary pump, giving it a two stage operation under certain circumstances to be explained.
3 - A turbine which receives the fluid impulse from the pump and is actually the driven member, being coupled to the propeller shaft.
4 - A primary stator.
5 - A secondary stator which provides the torque conversion functions of the unit. Both stators may either free-wheel or lock on over-running clutches.


SECONDARY STATOR
PRIMARY PUMP
PRIMARY STATOR
TURBINE
SECONDARY PUMP
PRIMARY STATOR OVER-RUNNING CLUTCH
FRONT OIL PUMP
LOW-BRAKE BAND
HIGH-CLUTCH
REVERSE-BRAKE BAND
PLANET UNIT
BREATHER
UNIVERSAL JOINT
SECONDARY STATOR OVER-RUNNING CLUTCH
SECONDARY PUMP OVER-RUNNING CLUTCH
SPEEDOMETER
PARKING BRAKE
REAR OIL PUMP
OIL PAN
REVERSE-SERVO UNIT
STARTER RING GEAR
OIL SCREEN
CRANKSHAFT
LOW BAND ANCHOR VALVE

45-10. Sectional cut-away view of Dynaflow transmission showing Torque Converter and planetary units.

DYNAFLOW CONVERTER OPERATION

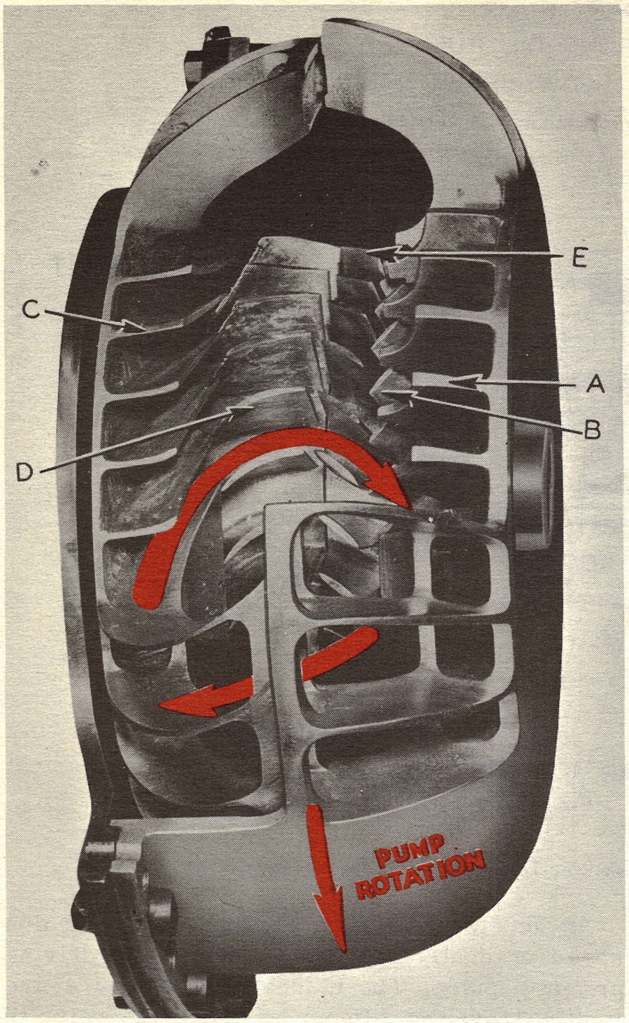
Let us consider the car as starting from a standing position and being accelerated to driving speed. The primary pump, driven directly from the flywheel, discharges oil against the vanes of the now stationary turbine. From the blades, the oil is deflected at tremendous velocity against the vanes of the stators. This force locks the stators in stationary position, permitting the stator vanes to reverse the oil flow back against the vanes of the secondary pump. This oil flow forces the secondary pump to free-wheel out of its way permitting the oil stream to re-enter the vanes of the primary pump at a more suitable angle thus increasing the torque or turning effort as the flow rejoins and augments the main oil stream from the pump driving the turbine. See Fig. 45-11.

Just before starting is the moment of extreme torque multiplication. At this moment the turbine and the stators are stationary and the primary pump is delivering its maximum accelerating effect.

The car starts as the turbine begins to revolve, turning with it the driveshaft to which it is splined.

As acceleration proceeds, the driven turbine speed gradually approaches that of the driving primary pump. The blades of the turbine are finally traveling almost at the same velocity as the oil from the primary pump which strikes them. With this relative velocity low, the oil no longer shoots off the turbine blades in a swift vortex flow to strike the blade faces of the stators with sufficient force to lock them stationary against their over-running clutches. Now, instead, the oil flow leaving the turbine strikes the backs of the stator blades releasing the over-running clutches causing them to free-wheel.

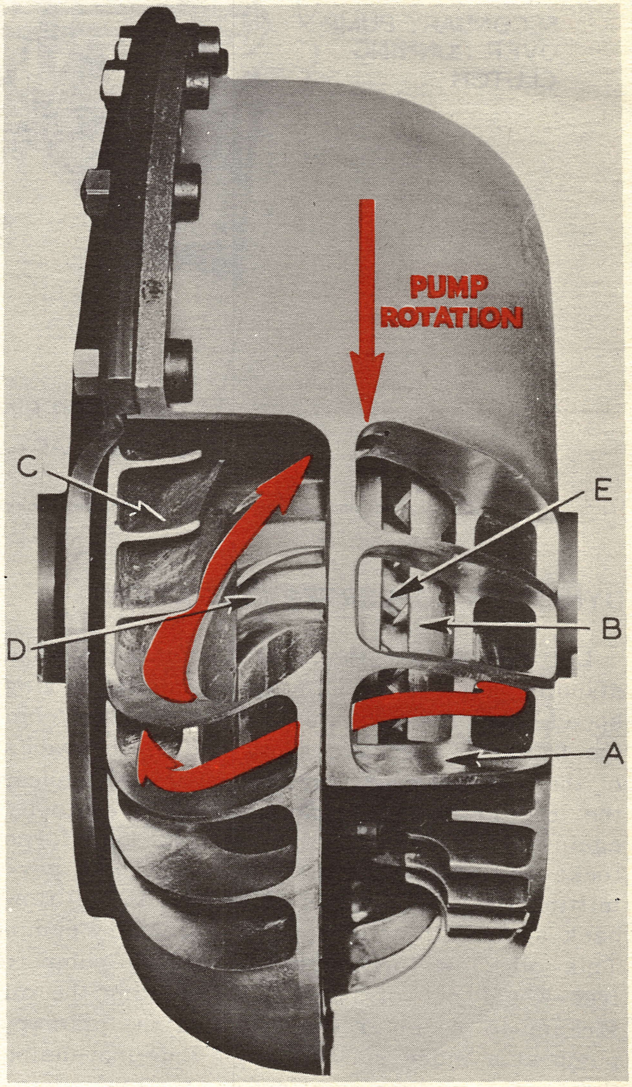
With the car running at steady speed over a level road, the return oil from the turbine flows against the blades of the secondary pump, undisturbed by the free-wheeling stator blades. The secondary pump over-running clutches now lock due to the reversed pressure of the oil on its blades. The secondary pump joins with the primary pump and rotates with it in unison to jointly form through their combined blade areas an efficient fluid coupling to the turbine. At this point, no torque multiplication is required and none takes place. The fluid flow in the coupling is uninterrupted by the stators as long as no reaction forces exist such as an



45-11. Oil flow in Torque Converter during acceleration. Primary pump A throws oil stream against turbine vanes. Oil stream after impact on turbine vanes is baffled by them into secondary stator D and primary stator E. The impact locks the stators against their over-running clutches, holding them stationary and permitting them to act as torque multipliers by diverting the oil stream back into the primary pump A. The secondary pump B, during this phase of operation, free-wheels out of operation. The diverted oil stream rejoins the flow through the pump contributing its energy to that of the main pump and multiplying the driving effort against the driven, or turbine member from which the power is transmitted to the driveshaft.

uphill grade, sand, mud, etc., which would lock the stators (by reducing the relative speed of the turbine) and cause them again to resume their functions as torque multipliers. See Fig. 45-12.

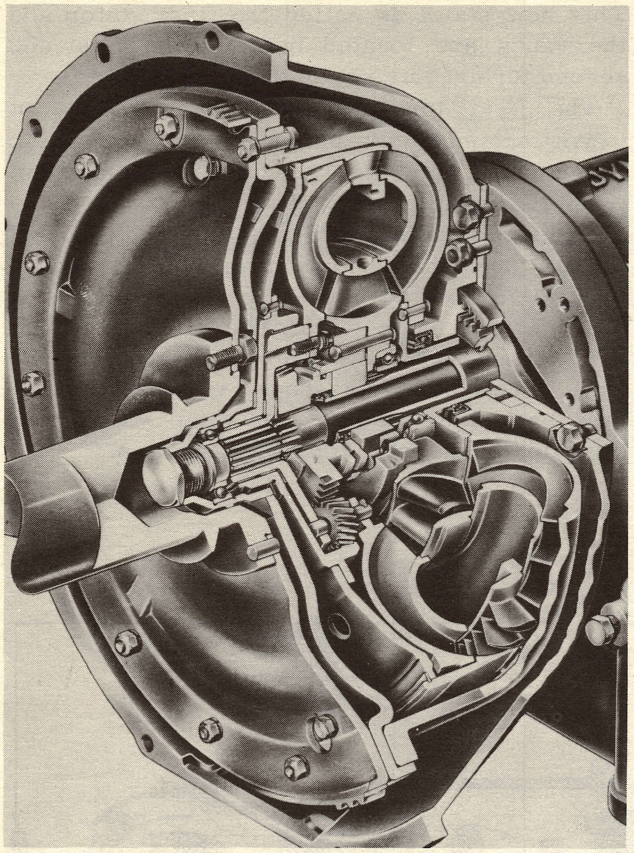
Thus the stators, which govern the amount of torque multiplication, derive their function automatically by the difference in velocity of the primary pump on the crankshaft and the turbine on the propeller shaft. As an uphill grade is encountered, the car and the turbine tend to slow. The driver automatically presses the accelerator to make the climb, thus speeding the engine and with it the primary pump. Up goes the difference in velocity between pump and turbine. The stators tend to lock more and more as this difference in speed increases. More and more oil flow is diverted back to the pump by the stators as they are slowed down by the increasing vortex pressure forcing the over-running clutches to begin to lock. Torque is thus increased more and more until the needs of the driver are met by the increased torque multiplication. This progression takes place



45-12. Oil flow in torque converter during steady, level driving. Primary pump A throws oil against turbine C giving it a straight hydraulic drive as a fluid coupling. Oil stream leaving the turbine blades which are rotating at approximately the same speed as primary pump blades or vanes, has consequently low vortex velocity. Stators are not now locked stationary on roller clutches since they are not under high vortex pressure of oil from the turbine, but can free-wheel. Oil stream under these conditions flows into vanes of secondary pump B which rotate in concert with vanes of primary pump A. This permits primary pump A and secondary pump B to rotate as a unit with the turbine to form a fluid coupling of high efficiency.

quietly and smoothly.

The driven shaft actuated by the turbine enters the transmission where it transmits the drive to the propeller shaft through a typical planetary gear box providing direct, emergency low, reverse and neutral.



45-13. Partial cut-away view of Twin Turbine Dynaflow showing installation of planetary gears within the turbine.

GEAR SHIFTING

Shifting into any of these positions is at the will of the driver by means of the lever on the steering column. Practically all driving is in the direct drive position and the torque converter smoothly and quietly meets all normal demands of the road and grade. The point of maximum torque multiplication corresponds to a gear ratio comparable with normal low gear in a conventional transmission. Only extremely tough grades or heavy going require a shift into "emergency low." It is very useful however in employing the engine as a brake down long mountain grades. In this case the turbine, driven by the propeller shaft, becomes the pump or driving member and the primary pump fixed to the engine crankshaft becomes the driven member.

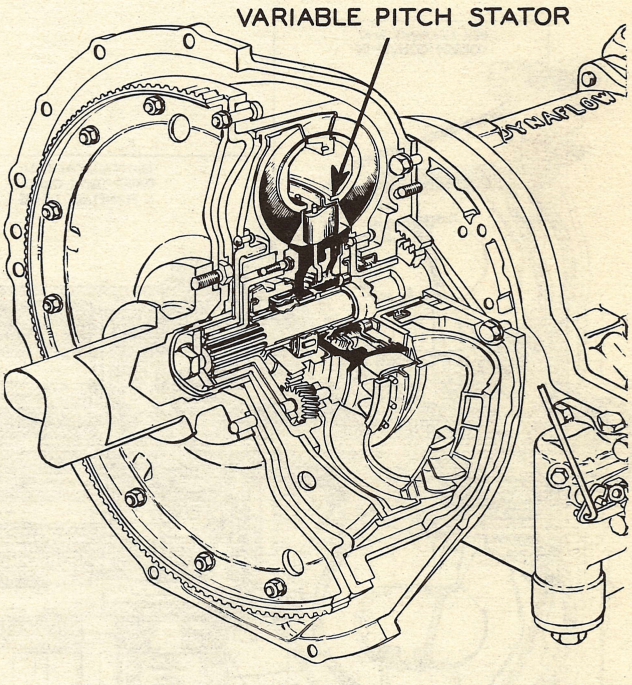
TWIN TURBINE DYNAFLOW

In 1953 the Dynaflow adopted a four element torque converter having geared turbines replacing the five element converter used previously. This change in design made for improved performance as the gears in the turbines served to further multiply the torque.

The units of the later design are known as: the pump, first turbine, second turbine and stator. See Fig. 45-13. The turbines are connected through a planetary gear set consisting of a ring gear, four planet pinions, a planet pinion carrier and a sun gear.

A single converter pump is attached to the flywheel of the engine and replaced the primary and secondary pumps of the previous models.

The first and second turbines replace the single turbine previously used and are interconnected with the planetary gear set. The first turbine is assembled to the ring gear of the planetary gear set, while the second turbine is bolted to the planet pinion carrier which in turn is connected to the output shaft.



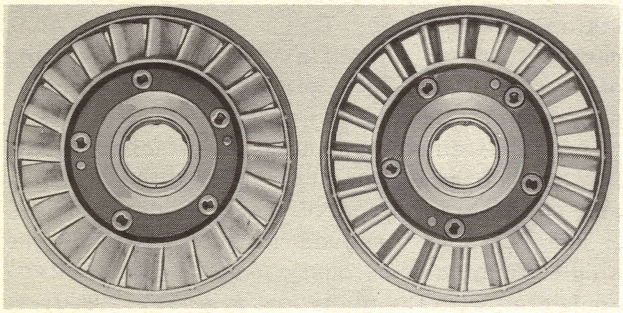
45-14. Opening of the throttle will change angle of stator blades for maximum torque during rapid acceleration.

A single stator replaces the primary and secondary stators used previously and is mounted on a free-wheeling clutch. The sun gear of the planetary gear set and the stator are coupled to the free-wheeling cam.

The Twin Turbine converter therefore has one free-wheeling clutch as compared to three used in the previous Dynaflow.

DYNAFLOW VARIABLE VANE

Principal feature of the 1955 Dynaflow transmission was the adoption of variable pitch stator blades which shift automatically. The construction of the stator is shown in Fig. 45-14, and the blades in open and closed position in Fig. 45-15.



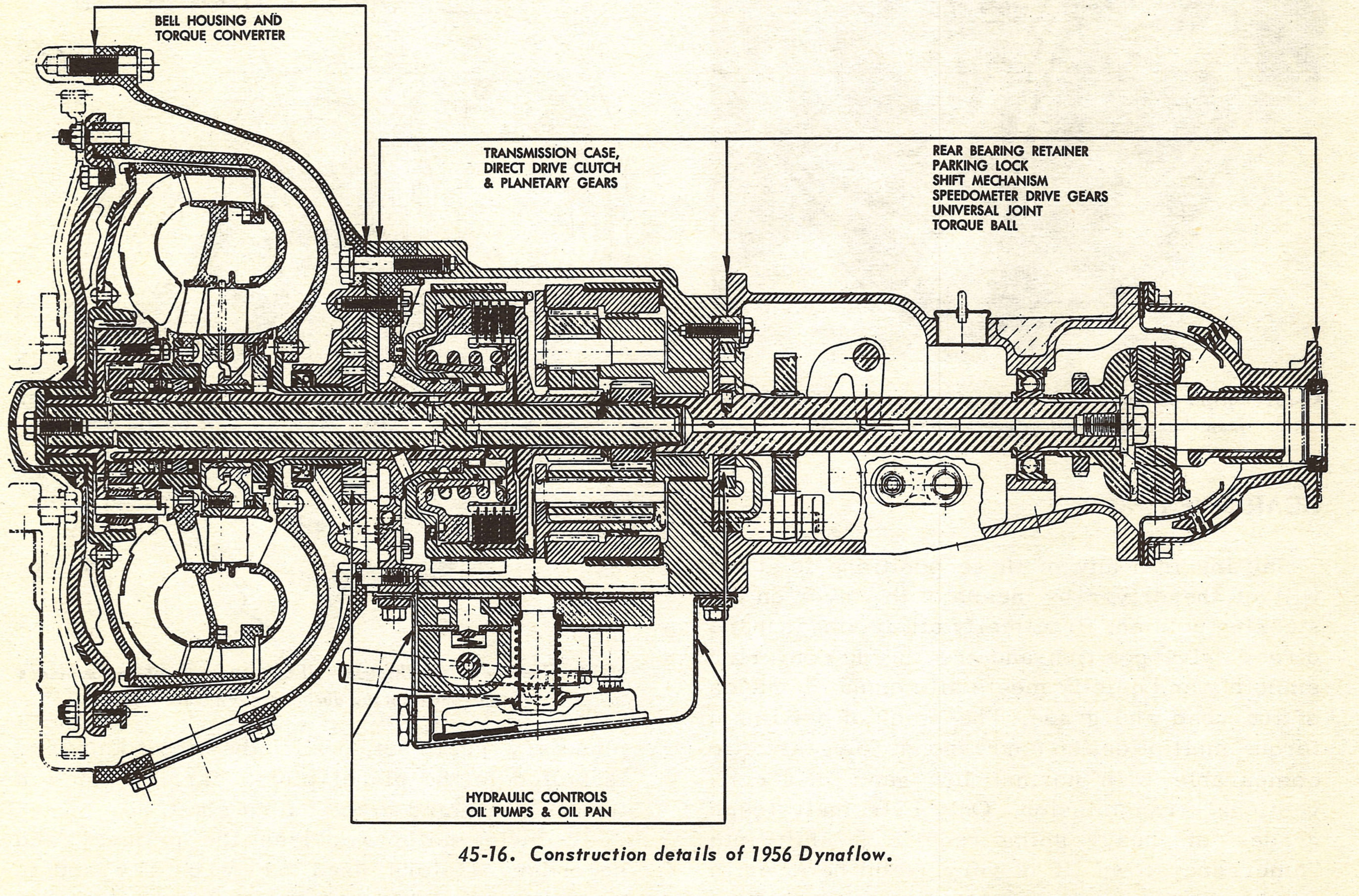
45-15. Stator blades in high angle at left and in low angle for ordinary driving at right.

Each of the 20 blades of the stator assembly is mounted on an individual crank pin, which is actuated by the stator piston. Oil pressure to one or both sides of the piston moves the blades to either high or low angle position. The low angle is used for cruising and the high angle for rapid acceleration. The position of the stator blade angle depends on throttle position.

1956 DYNAFLOW

To increase low speed performance under full throttle, a new stator was added in 1956. This new stator is called the first stator and the vanes are located between the first and second turbines as shown in Fig. 45-16.

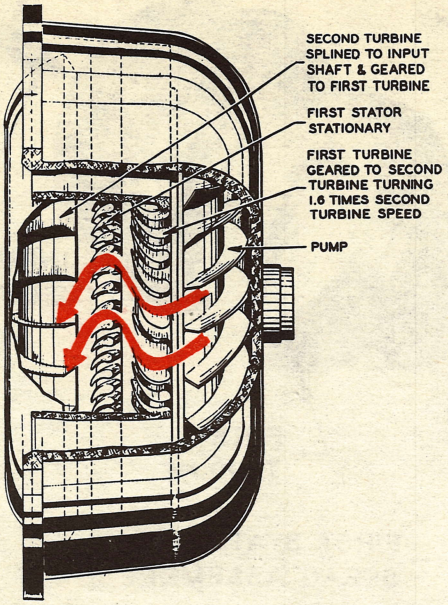
The first turbine has a narrow band of vanes located at the pump exit in a position to receive the spinning cylinder of oil projected from the pump. The first stator has a similar band of narrow vanes located between the first turbine and the second turbine. The second turbine is located inside the first turbine in position to receive oil directed to it from the first turbine and first stator. This turbine has a broad band of vanes shaped to direct the oil flow back into the variable pitch stator in a direction opposite to converter rotation.


BELL HOUSING AND TORQUE CONVERTER
TRANSMISSION CASE, DIRECT DRIVE CLUTCH & PLANETARY GEARS
REAR BEARING RETAINER
PARKING LOCK
SHIFT MECHANISM
SPEEDOMETER DRIVE GEARS
UNIVERSAL JOINT
TORQUE BALL
HYDRAULIC CONTROLS OIL PUMPS & OIL PAN

45-16. Construction details of 1956 Dynaflow.

Both turbines transmit driving force or torque during acceleration. At higher car speeds and at cruising speeds, the second turbine transmits all the driving force. This is shown in Figs. 45-17 and 45-18.

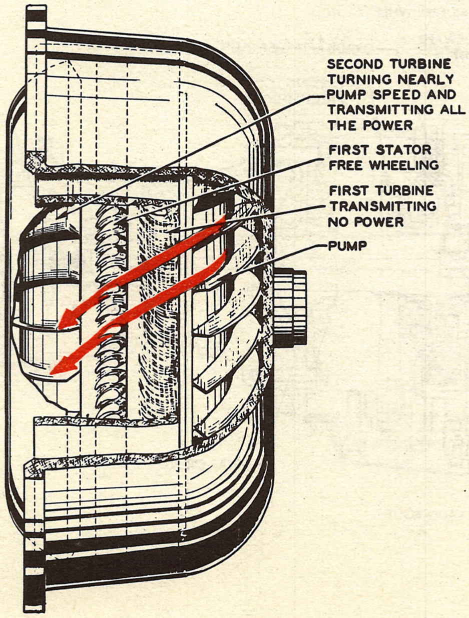
The oil leaving the second turbine then


SECOND TURBINE SPLINED TO INPUT SHAFT & GEARED TO FIRST TURBINE
FIRST STATOR STATIONARY
FIRST TURBINE GEARED TO SECOND TURBINE TURNING 1.6 TIMES SECOND TURBINE SPEED
PUMP

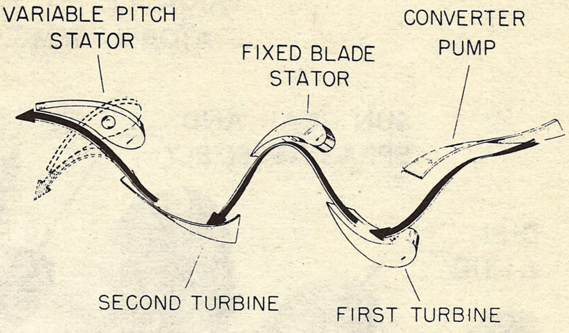
45-17. During acceleration, oil flows from pump to second turbine as shown here.

enters the variable pitch stator where it is redirected before re-entering the converter pump.

The flow of oil in this sequence is shown in Fig. 45-19. The pump member energizes the oil and causes it to flow to the first turbine. Here its flow direction changes from the entrance end to the exit end of the blade causing a driving force to be imposed on the first turbine. The fixed blade first stator then redirects the oil flow so that it will enter the second turbine at an angle which provides a driving force on the second turbine.


SECOND TURBINE TURNING NEARLY PUMP SPEED AND TRANSMITTING ALL THE POWER
FIRST STATOR FREE WHEELING
FIRST TURBINE TRANSMITTING NO POWER
PUMP

45-18. While cruising, the angle of oil flow changes to become more direct.


VARIABLE PITCH STATOR
FIXED BLADE STATOR
CONVERTER PUMP
SECOND TURBINE
FIRST TURBINE

45-19. Diagram of oil flow through various elements of 1956 Dynaflow.

BUICK FLIGHT PITCH

The 1958 version of the Buick Dynaflow Automatic transmission is known as the "Flight Pitch," and incorporates a number of changes. The design is shown in Fig. 45-21. It will be noted that the bands previously used on the planetary drums have been discarded and replaced with multiple disc clutches. Also a grade retarder has been added to assist in slowing the car.

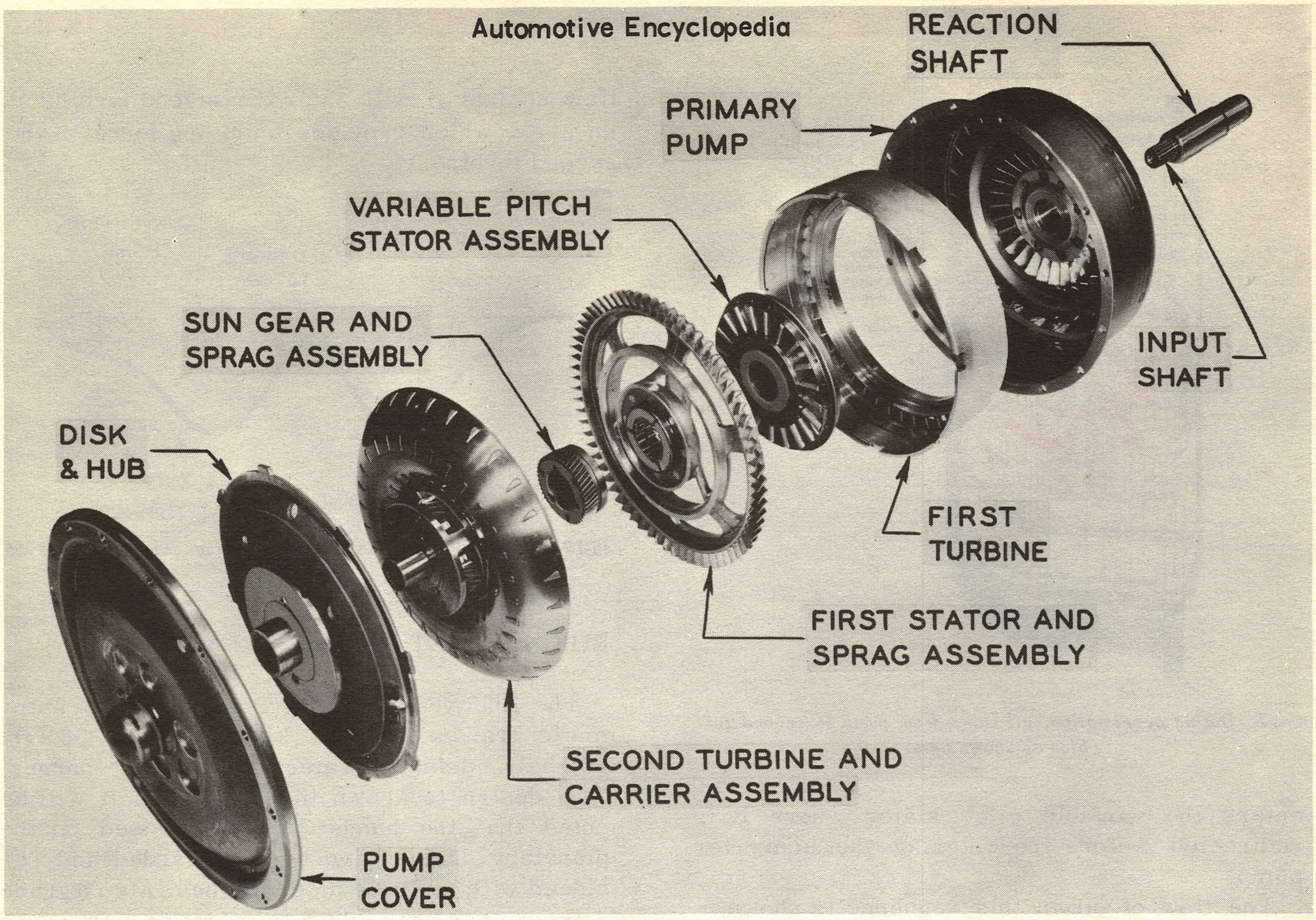
The five-element torque converter embodies three turbines. Two of these turbines are connected individually to the output shaft through the two planetary gear sets. The third turbine is connected directly to the output shaft. Thus all three of the turbines combine to deliver power.

In conjunction with the turbines the multiple pitch stator is used. This as previously described herein has a control system whereby the pressure on the foot accelerator pedal shifts the stator blades to the most efficient position.

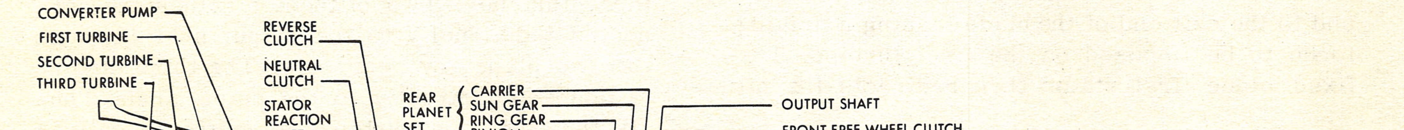
The three turbines in connection with the variable pitch stator operate as follows: When starting, the converter pump applies force to the blades of the first turbine. This driving force is multiplied by the planetary gears attached to the first turbine by the ratio of 2.86-1. Very little force is applied to the second and third turbines at this time.

As the car speed increases, the force of the first turbine gradually decreases and the second turbine starts to take over. The second turbine is connected to another planetary gear set with a ratio of 1.54-1.

With a further increase in car speed the force of the second turbine decreases and the third turbine steps in and as it has no gear reduction, the power is applied directly to the output shaft.


REACTION SHAFT
PRIMARY PUMP
VARIABLE PITCH STATOR ASSEMBLY
SUN GEAR AND SPRAG ASSEMBLY
INPUT SHAFT
DISK & HUB
FIRST TURBINE
FIRST STATOR AND SPRAG ASSEMBLY
SECOND TURBINE AND CARRIER ASSEMBLY
PUMP COVER

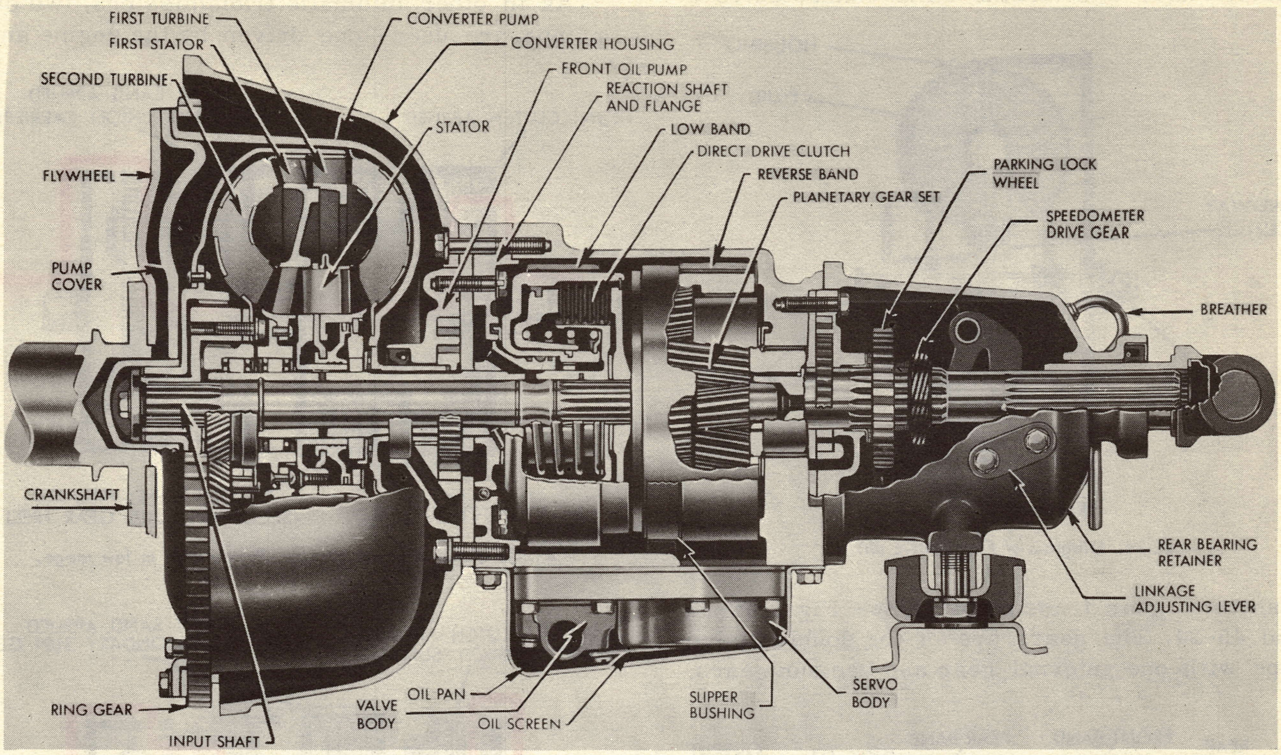
45-20. *1956 Dynaflow converter assembly as exploded.*


CONVERTER PUMP
FIRST TURBINE
SECOND TURBINE
THIRD TURBINE
FLIGHT PITCH STATOR
REVERSE CLUTCH
NEUTRAL CLUTCH
STATOR REACTION SHAFT
REAR PLANET SET
CARRIER
SUN GEAR
RING GEAR
PINION
FRONT PLANET SET
PINION
RING GEAR
SUN GEAR
CARRIER
OUTPUT SHAFT
FRONT FREE WHEEL CLUTCH
REAR FREE WHEEL CLUTCH
FORWARD CLUTCH
GRADE RETARDER CLUTCH
PARKING LOCK RATCHET WHEEL
UNIVERSAL JOINT
REAR OIL PUMP
VALVE BODY
FRONT OIL PUMP
TRANSMISSION CASE
FIRST TURBINE SHAFT
THIRD TURBINE SHAFT
SECOND TURBINE SHAFT

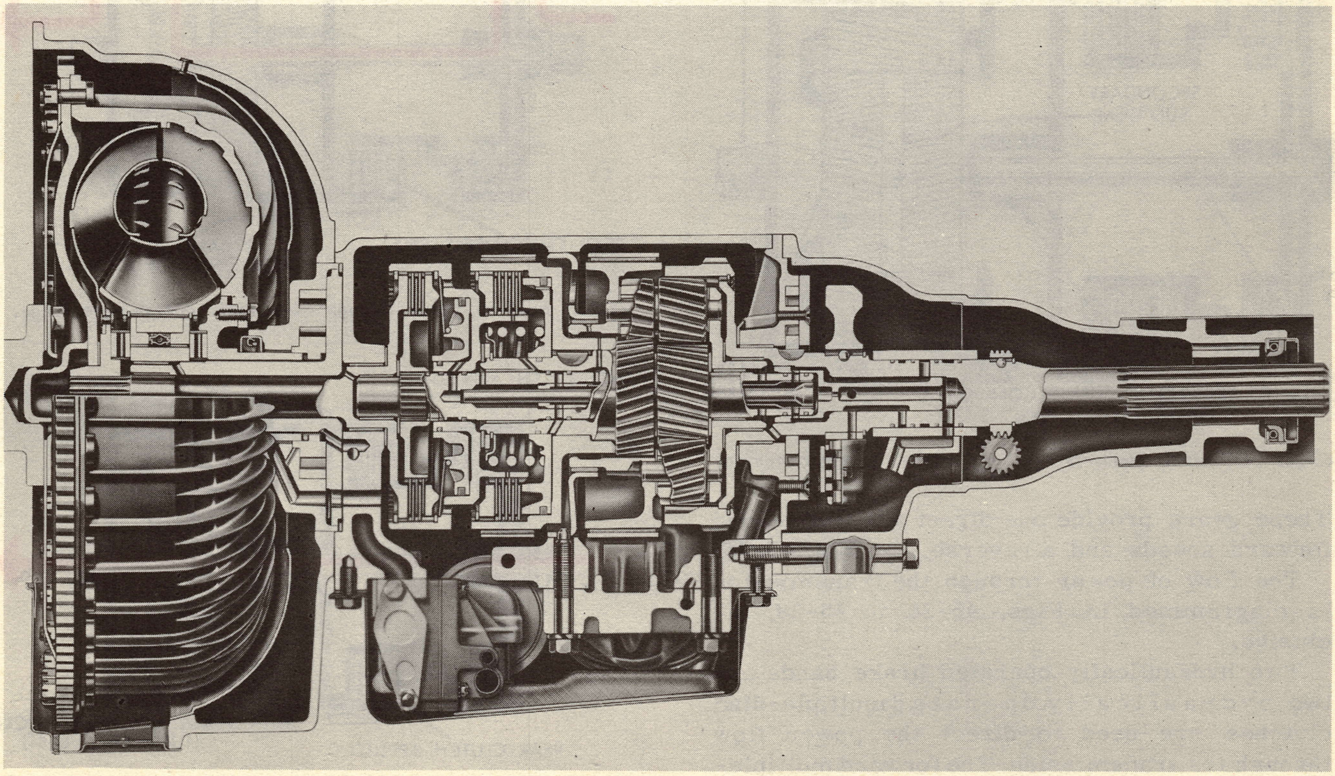
45-21. *Cross section of 1958 Buick Flight Pitch Dynaflow Automatic transmission.*

Thus the third turbine is handling all the engine power and no torque conversion is occurring. At cruising speeds the first and second turbines do not transfer any power as the over-running clutches allow them to free-wheel.

The grade retarder has fins or paddles on a rotating plate. When applied these paddles agitate the oil in the housing to create resistance to the rotation and thus slow the car.


FIRST TURBINE
FIRST STATOR
SECOND TURBINE
CONVERTER PUMP
CONVERTER HOUSING
FRONT OIL PUMP
REACTION SHAFT AND FLANGE
STATOR
LOW BAND
DIRECT DRIVE CLUTCH
REVERSE BAND
PLANETARY GEAR SET
PARKING LOCK WHEEL
SPEEDOMETER DRIVE GEAR
BREATHER
FLYWHEEL
PUMP COVER
CRANKSHAFT
REAR BEARING RETAINER
LINKAGE ADJUSTING LEVER
SERVO BODY
SLIPPER BUSHING
OIL PAN
VALVE BODY
OIL SCREEN
RING GEAR
INPUT SHAFT

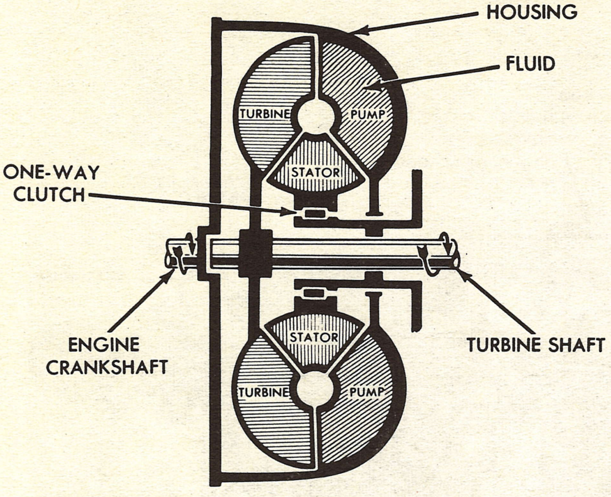
45-22. 1961 Buick automatic transmission known as "Turbine Drive."



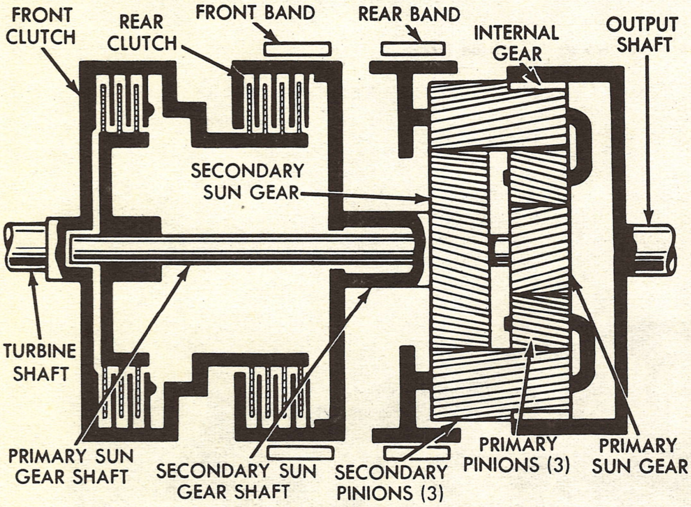
45-23. Fordomatic drive is through both torque converter and planetary gearing in all speeds.

FORDOMATIC

The Fordomatic is of the air-cooled torque converter type using three elements; the usual pump, stator and turbine units connected to a planetary gear transmission. See Figs. 45-23 and 45-24. The gears are of the double pinion type with one internal gear and two sun gears.


HOUSING
FLUID
TURBINE
PUMP
STATOR
ONE-WAY CLUTCH
STATOR
TURBINE
PUMP
ENGINE CRANKSHAFT
TURBINE SHAFT

45-24. *Diagram of Fordomatic units.*


FRONT CLUTCH
REAR CLUTCH
FRONT BAND
REAR BAND
INTERNAL GEAR
OUTPUT SHAFT
SECONDARY SUN GEAR
TURBINE SHAFT
PRIMARY SUN GEAR SHAFT
SECONDARY SUN GEAR SHAFT
SECONDARY PINIONS (3)
PRIMARY PINIONS (3)
PRIMARY SUN GEAR

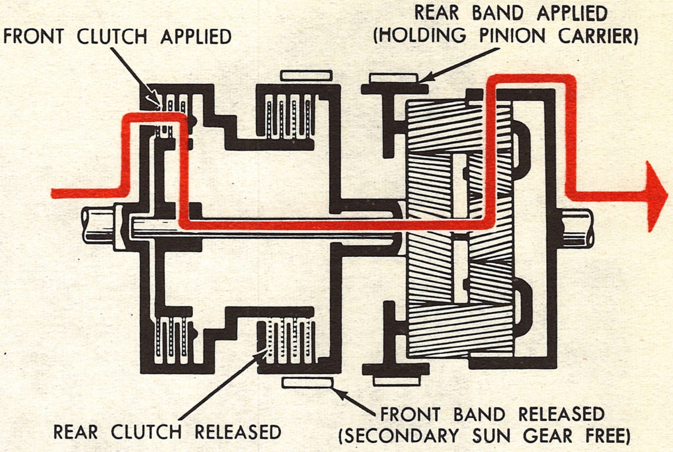
45-25. *Principal elements of Fordomatic planetary design.*

These gears provide one direct and two geared forward speeds and a reverse. See Fig. 45-25.

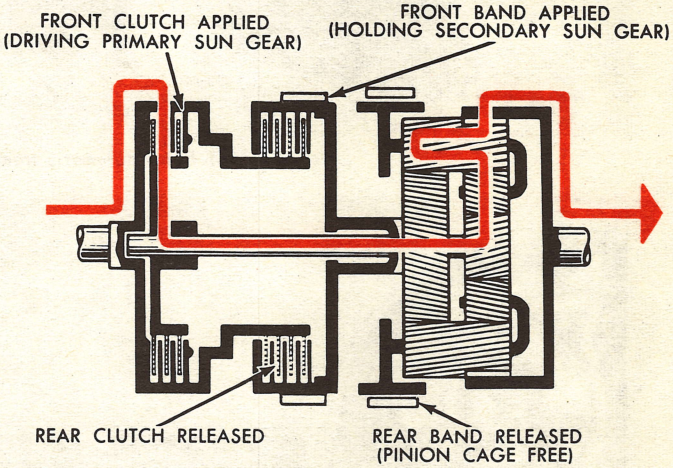
The flow of power through the transmission is diagrammed in Figs. 45-26 to 45-29, inclusive.

Two hydraulically operated brake bands and two hydraulically operated multiple-disc clutches are used to direct the power flow through the transmission. The forward multiple-disc clutch is engaged for all forward speeds and disengaged in neutral and reverse positions. The rear clutch is engaged in high and reverse. The forward band is applied in intermediate gear (Fig. 45-27) while the rear band is applied in both low and reverse (Figs. 45-26 and 45-29).

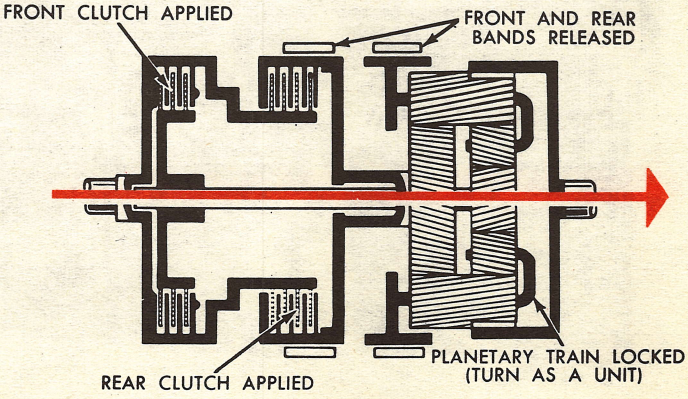
As in other automatic transmissions, two oil pumps are used--one driven by the engine and


FRONT CLUTCH APPLIED
REAR BAND APPLIED (HOLDING PINION CARRIER)
REAR CLUTCH RELEASED
FRONT BAND RELEASED (SECONDARY SUN GEAR FREE)

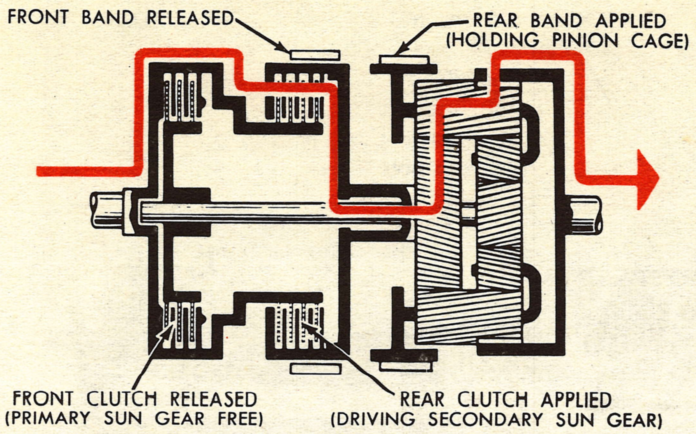
45-26. *Flow of power through Fordomatic in low range.*


FRONT CLUTCH APPLIED (DRIVING PRIMARY SUN GEAR)
FRONT BAND APPLIED (HOLDING SECONDARY SUN GEAR)
REAR CLUTCH RELEASED
REAR BAND RELEASED (PINION CAGE FREE)

45-27. *Flow of power through Fordomatic intermediate range.*


FRONT CLUTCH APPLIED
FRONT AND REAR BANDS RELEASED
PLANETARY TRAIN LOCKED (TURN AS A UNIT)
REAR CLUTCH APPLIED

45-28. *Flow of power through Fordomatic in high range.*


FRONT BAND RELEASED
REAR BAND APPLIED (HOLDING PINION CAGE)
FRONT CLUTCH RELEASED (PRIMARY SUN GEAR FREE)
REAR CLUTCH APPLIED (DRIVING SECONDARY SUN GEAR)

45-29. Flow of power through Fordomatic in reverse.

the other driven from the propeller shaft. These pumps supply oil under pressure to operate the control bands and clutches, lubricate the entire transmission and keep the converter filled.

The control system consists of a selector lever on the steering post having five positions, a valve body in the transmission, a hydraulic governor on the output shaft and a pressure regulator assembly. These units are all interconnected to provide the necessary manual and automatic selection of speeds.

CHRYSLER POWERFLITE

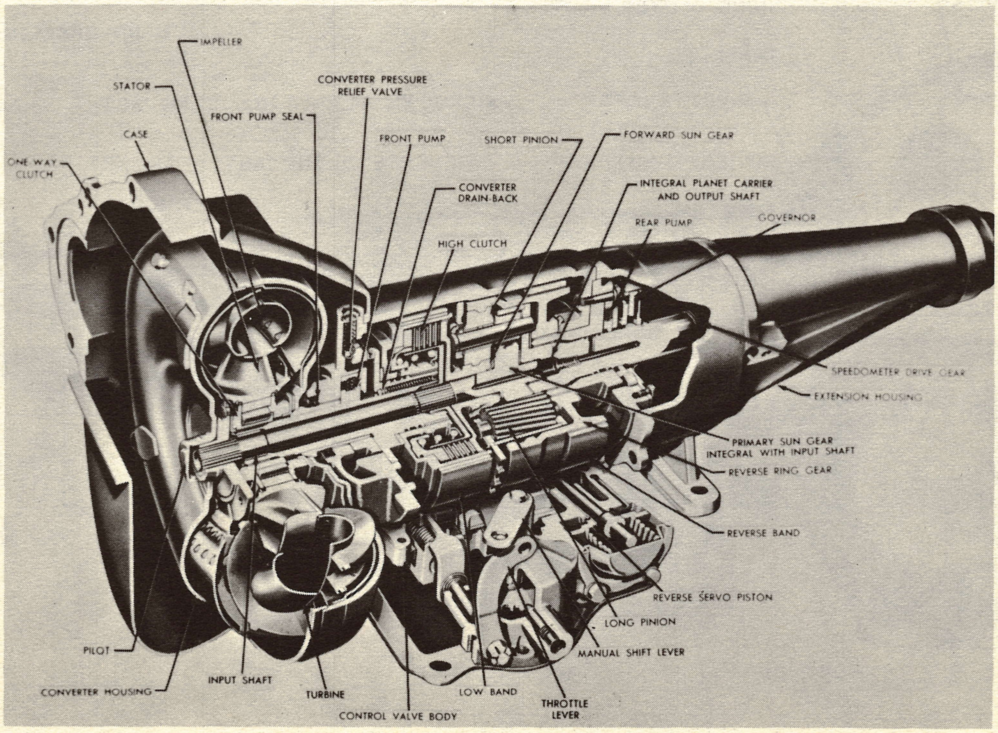
Fully automatic in operation, the PowerFlite transmission is made by the Chrysler Corporation. The construction of the first series is shown in Fig. 45-31.

The design was changed to use a single stator instead of two stators in later models. See Fig. 45-32.

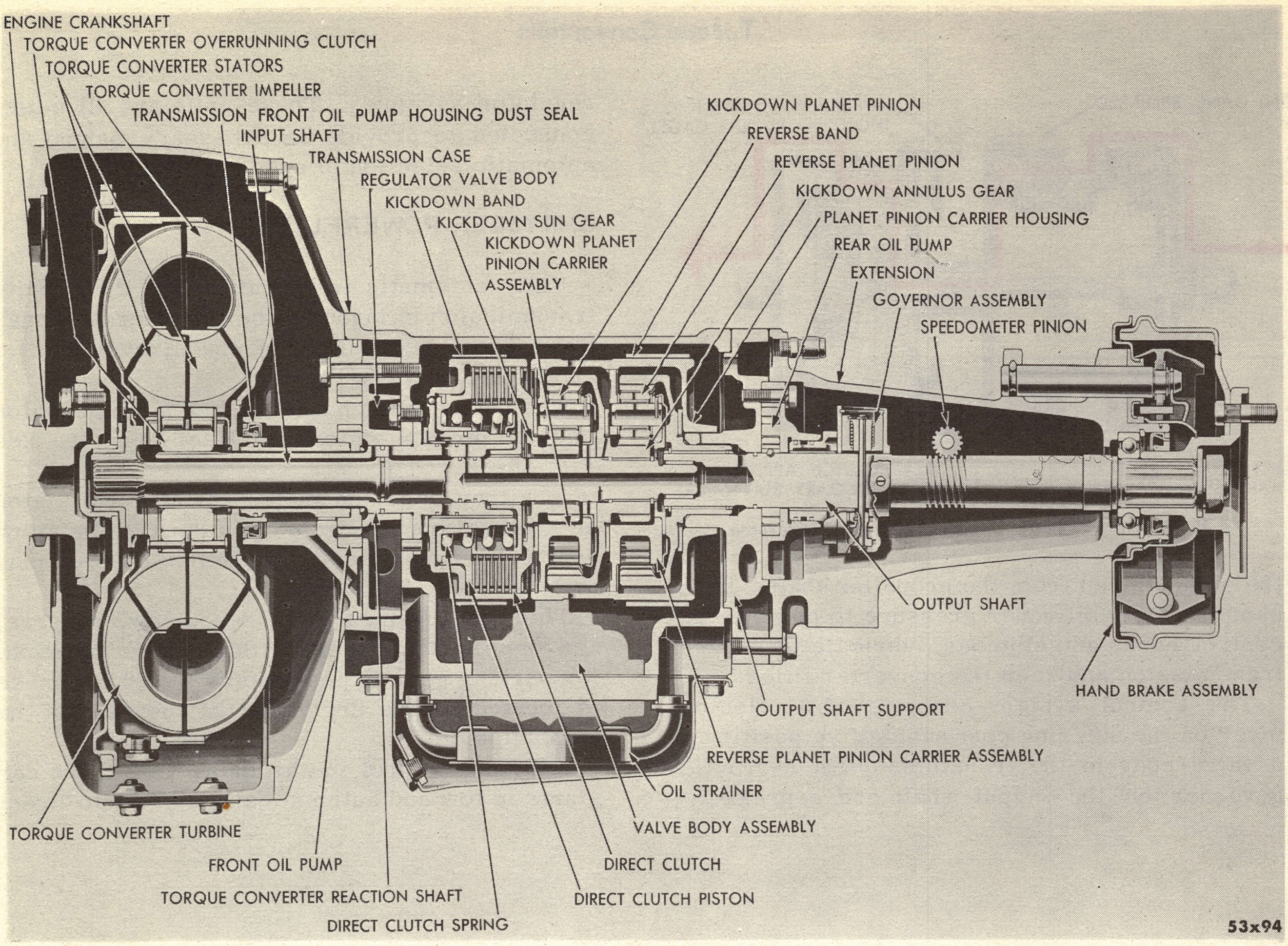
In either case the pump, turbine and stator or stators are connected to a pair of planetary gear units hydraulically controlled by two bands and a multiple disc clutch.

This arrangement provides a low, reverse, and driving range along with a neutral position. No parking gear is provided as a parking brake is located on the driveshaft at the rear of the transmission.

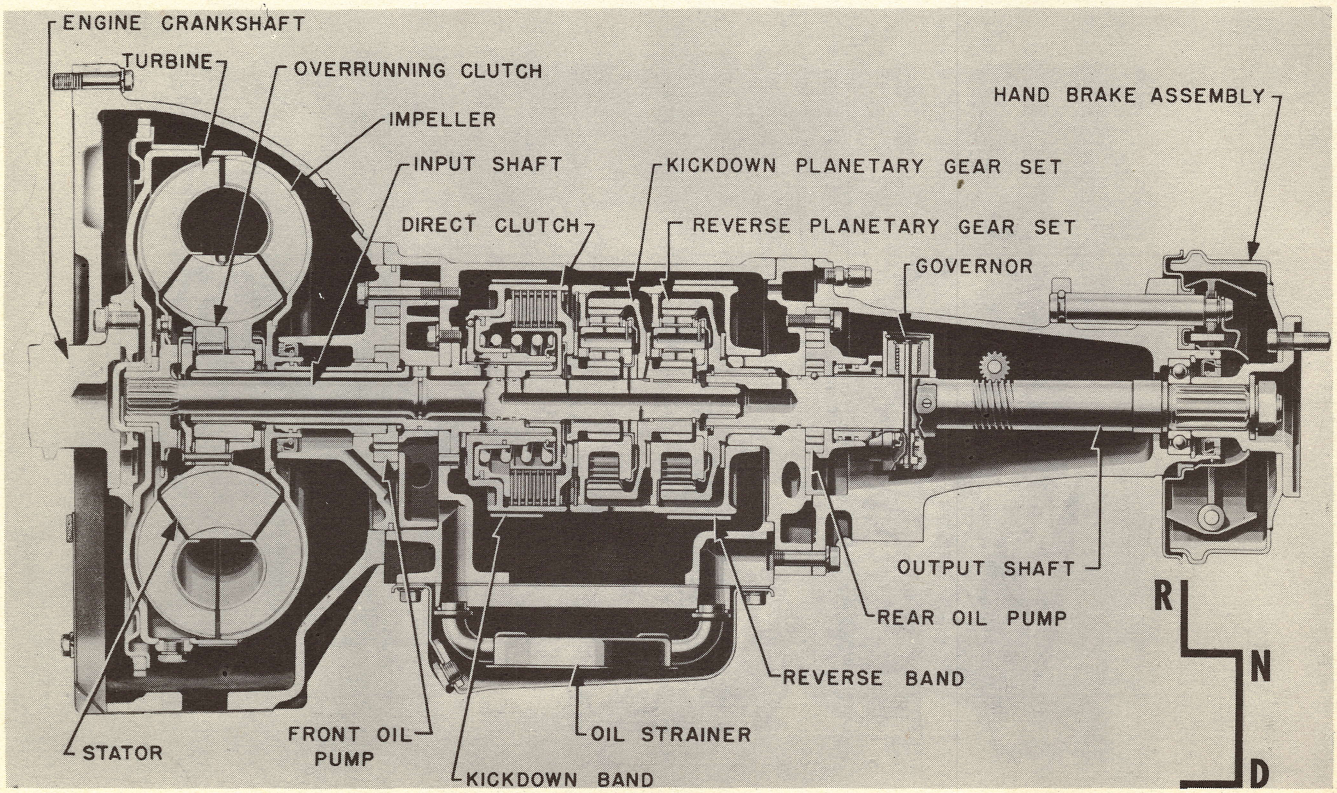
With the control in the drive range, the car starts in low and automatically shifts into direct


IMPELLER
STATOR
CONVERTER PRESSURE RELIEF VALVE
FRONT PUMP SEAL
CASE
FRONT PUMP
SHORT PINION
FORWARD SUN GEAR
ONE WAY CLUTCH
CONVERTER DRAIN-BACK
INTEGRAL PLANET CARRIER AND OUTPUT SHAFT
REAR PUMP
GOVERNOR
HIGH CLUTCH
SPEEDOMETER DRIVE GEAR
EXTENSION HOUSING
PRIMARY SUN GEAR INTEGRAL WITH INPUT SHAFT
REVERSE RING GEAR
REVERSE BAND
REVERSE SERVO PISTON
LONG PINION
MANUAL SHIFT LEVER
PILOT
INPUT SHAFT
CONVERTER HOUSING
TURBINE
LOW BAND
THROTTLE LEVER
CONTROL VALVE BODY

45-30. 1961 version of Ford Automatic Transmission.


ENGINE CRANKSHAFT
TORQUE CONVERTER OVERRUNNING CLUTCH
TORQUE CONVERTER STATORS
TORQUE CONVERTER IMPELLER
TRANSMISSION FRONT OIL PUMP HOUSING DUST SEAL
INPUT SHAFT
TRANSMISSION CASE
REGULATOR VALVE BODY
KICKDOWN BAND
KICKDOWN SUN GEAR
KICKDOWN PLANET PINION CARRIER ASSEMBLY
KICKDOWN PLANET PINION
REVERSE BAND
REVERSE PLANET PINION
KICKDOWN ANNULUS GEAR
PLANET PINION CARRIER HOUSING
REAR OIL PUMP
EXTENSION
GOVERNOR ASSEMBLY
SPEEDOMETER PINION
OUTPUT SHAFT
HAND BRAKE ASSEMBLY
OUTPUT SHAFT SUPPORT
REVERSE PLANET PINION CARRIER ASSEMBLY
OIL STRAINER
VALVE BODY ASSEMBLY
DIRECT CLUTCH
DIRECT CLUTCH PISTON
TORQUE CONVERTER TURBINE
FRONT OIL PUMP
TORQUE CONVERTER REACTION SHAFT
DIRECT CLUTCH SPRING
53x94

45-31. Cross section of first PowerFlite series with two stators.

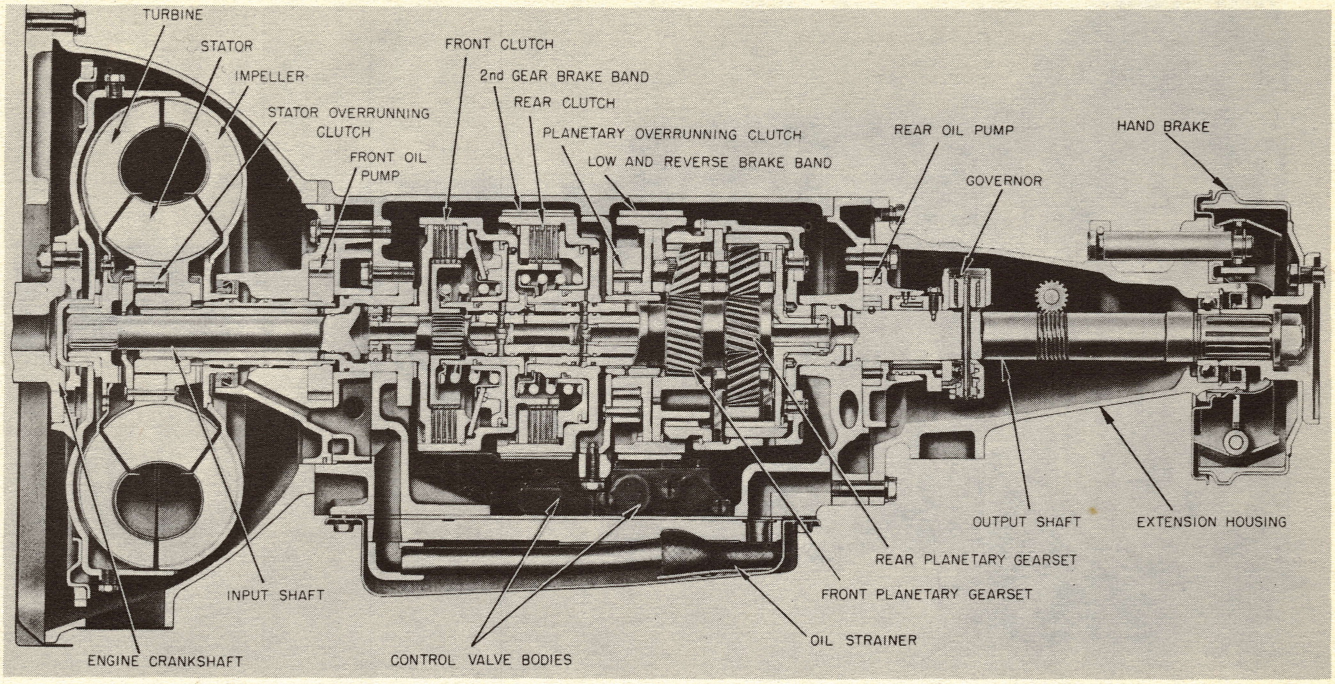

ENGINE CRANKSHAFT
TURBINE
OVERRUNNING CLUTCH
IMPELLER
INPUT SHAFT
DIRECT CLUTCH
KICKDOWN PLANETARY GEAR SET
REVERSE PLANETARY GEAR SET
GOVERNOR
HAND BRAKE ASSEMBLY
OUTPUT SHAFT
REAR OIL PUMP
REVERSE BAND
OIL STRAINER
KICKDOWN BAND
FRONT OIL PUMP
STATOR
R
N
D

45-32. Later design PowerFlite uses a single stator.

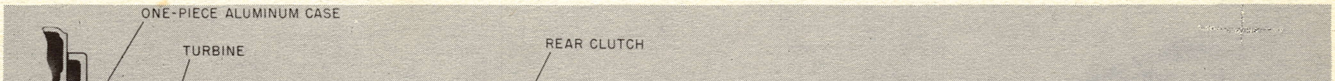
drive as the car speed increases. Also as the car speed decreases, the transmission will down-shift into low gear. By pressing the accelerator to the floor when in direct drive the transmission will down-shift automatically for passing another car.

CHEVROLET POWERGLIDE

The Powerglide is of the torque converter type and uses planetary gears and hydraulic controls somewhat like the Buick Dynaflow


TURBINE
STATOR
IMPELLER
STATOR OVERRUNNING CLUTCH
FRONT OIL PUMP
FRONT CLUTCH
2nd GEAR BRAKE BAND
REAR CLUTCH
PLANETARY OVERRUNNING CLUTCH
LOW AND REVERSE BRAKE BAND
REAR OIL PUMP
GOVERNOR
HAND BRAKE
OUTPUT SHAFT
EXTENSION HOUSING
REAR PLANETARY GEARSET
FRONT PLANETARY GEARSET
OIL STRAINER
INPUT SHAFT
ENGINE CRANKSHAFT
CONTROL VALVE BODIES

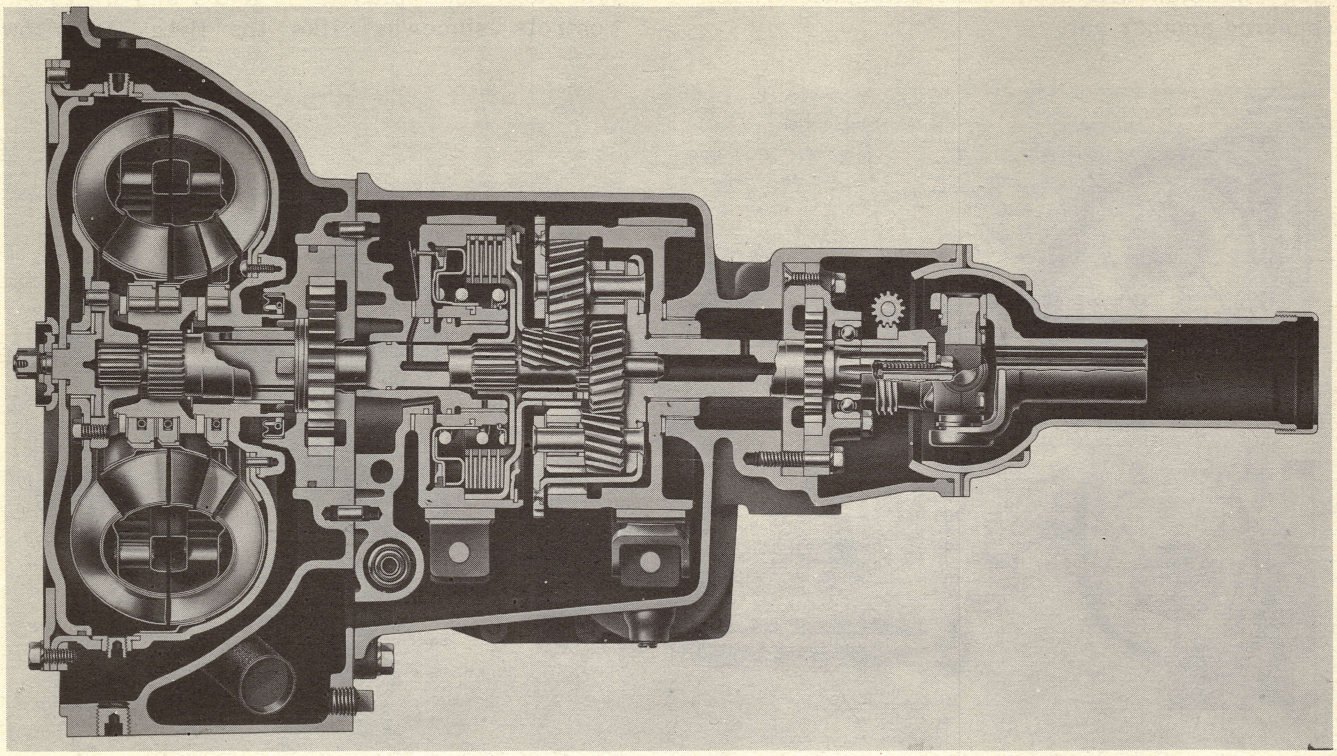
45-33. Cross section of Chrysler Torque-Flite automatic transmission.


ONE-PIECE ALUMINUM CASE
TURBINE
STATOR
IMPELLER
FRONT OIL PUMP
FRONT CLUTCH
REAR CLUTCH
FRONT PLANETARY GEAR SET
REAR PLANETARY GEAR SET
LOW & REVERSE BAND
PLANETARY OVERRUNNING CLUTCH
GOVERNOR
OUTPUT SHAFT
SPEEDOMETER PINION
EXTENSION HOUSING
PARKING SPRAG ASSEMBLY
REAR OIL PUMP
CONTROL VALVE BODY
OIL STRAINER
SUN GEAR DRIVING SHELL
IMPUT SHAFT
FLEXIBLE DRIVE PLATE
ENGINE CRANKSHAFT
FRONT CLUTCH BAND
(Kickdown)

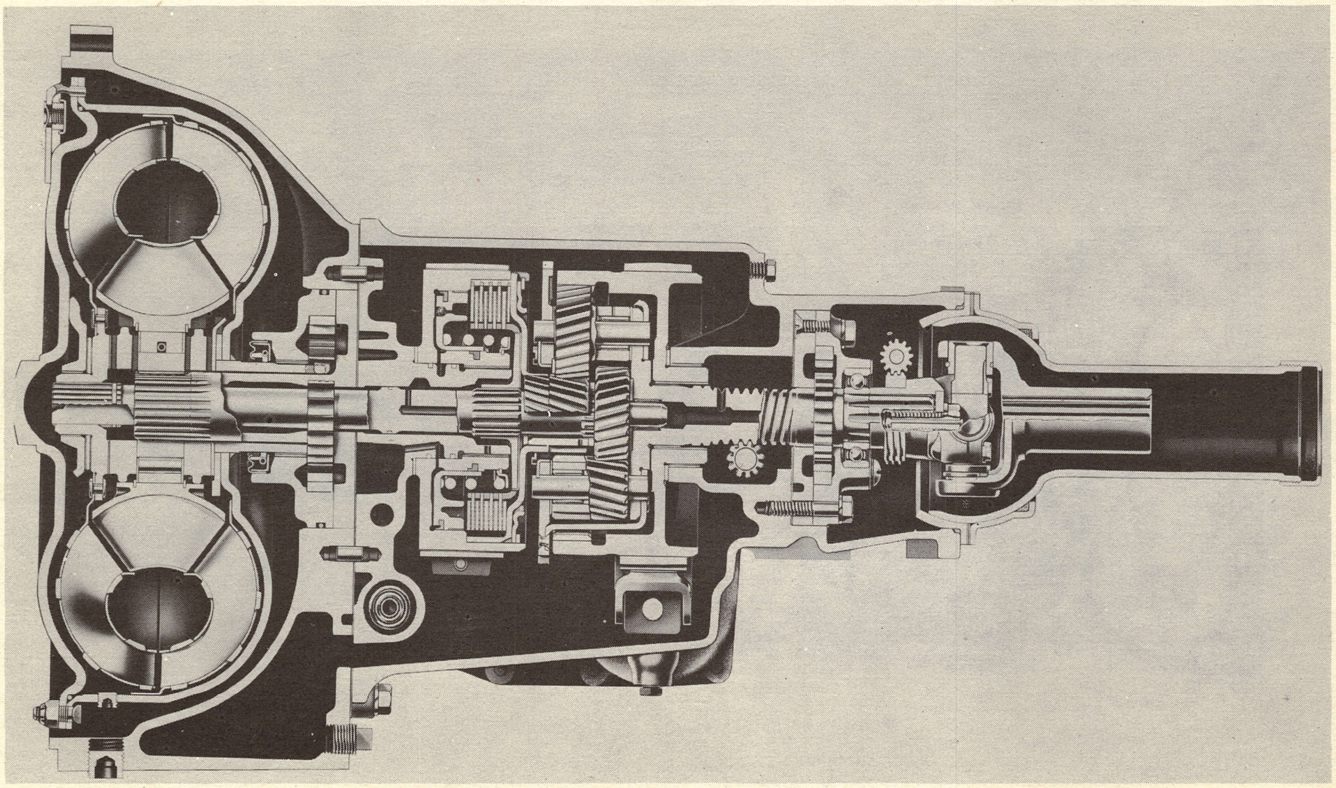
45-34. 1962 automatic transmission as built by Chrysler. This replaced both Torque-Flite and PowerFlite for Dodge V-8 models.

described in a preceding chapter. See Fig. 45-35.

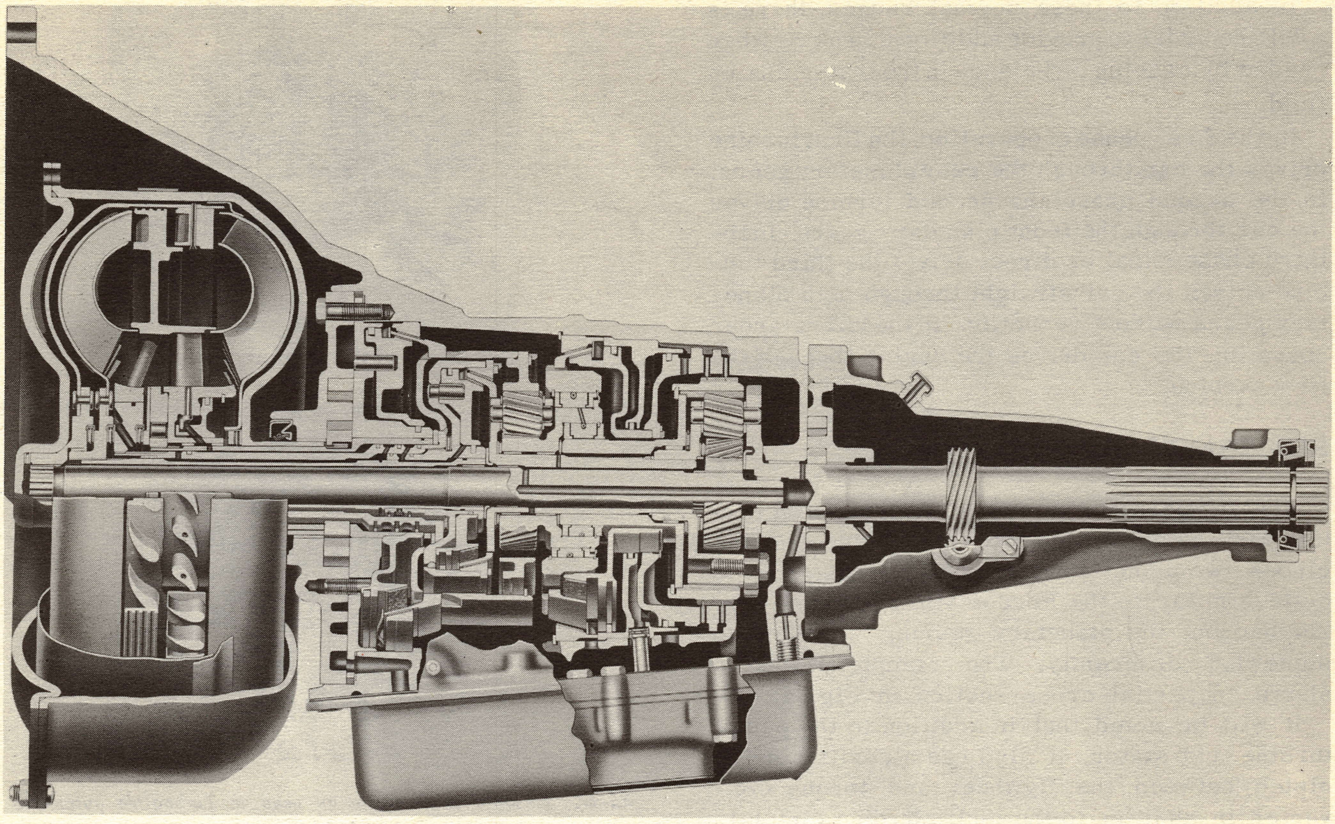
For the 1953 models, the Powerglide torque converter was changed to a three element design and the overrun coupling was eliminated. Comparison of Figs. 45-35 and 45-36 illustrate the changes in design. Also an automatic shift from low to high and automatic down shifting



45-35. *First version of Powerglide had a five element converter and an "overrun coupling" to act as a car retarder.*



45-36. *This cross section of the later model Powerglide shows the changes made in the torque converter units.*



45-37. Cross section of Chevrolet Turboglide automatic transmission.

was added.

The transmission is basically the same as previous models but to provide for the automatic shift a low-drive valve body and a governor were added.

This automatic shifting mechanism is sensitive to car speed (through the governor) and throttle position (through interconnection with the throttle). The vehicle starts in the low range and then automatically shifts into high in accordance with car speed and throttle opening. If the throttle is opened wider the transmission will not shift until a higher car speed is attained.

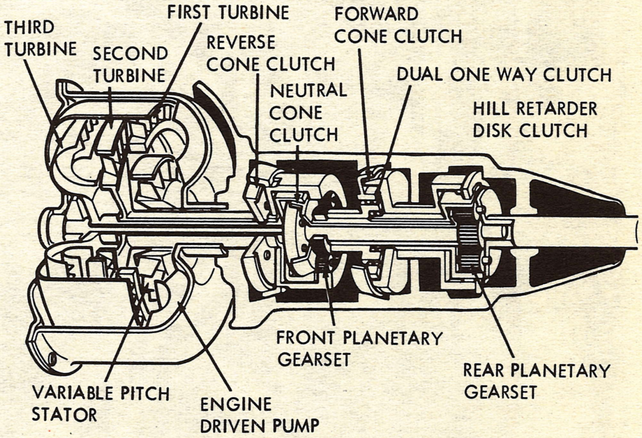
If the accelerator is pressed to the floor while the car is cruising at nominal speed the transmission will automatically downshift to low range. As soon as the speed increases sufficiently, it will again upshift automatically. Also when slowing down normally below a certain speed the downshift will occur.

This type of automatic control using a governor and a throttle valve in combination was thoroughly described previously in this text.

CHEVROLET TURBOGLIDE

Comparison of the Turboglide as used by Chevrolet with previous models of the Powerglide shows that the Turboglide is an entirely different transmission. See Fig. 45-37.

This transmission has three turbines in the torque converter which is connected to a pair of planetary gear sets which do not have bands on them. Cone clutches are used instead as shown in Fig. 45-38. The transmission is not shifted from one range to another but different ratios of gear reduction are available automatically. Also the stator blades have a variable angle which will provide quick acceleration when desired. See Fig. 45-39.


THIRD TURBINE
SECOND TURBINE
FIRST TURBINE
REVERSE CONE CLUTCH
NEUTRAL CONE CLUTCH
FORWARD CONE CLUTCH
DUAL ONE WAY CLUTCH
HILL RETARDER DISK CLUTCH
FRONT PLANETARY GEARSET
REAR PLANETARY GEARSET
VARIABLE PITCH STATOR
ENGINE DRIVEN PUMP

45-38. Elements of Turboglide converter and gears.

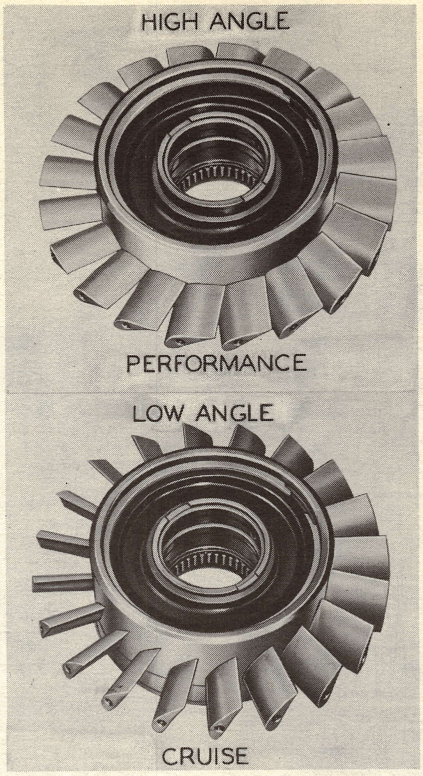
In addition to these normal ranges, there is a hill retarder to provide additional braking when needed by causing turbulence in the transmission fluid.

In the first phase of operation, the first turbine drives the car through the rear planetary gears. In the second phase the second turbine drives the car through the front planetary gears. In the third phase (final or direct drive) the third turbine drives the car straight through both planetary gears without reduction. In the hill retarder operation the car drives the engine through the first turbine.

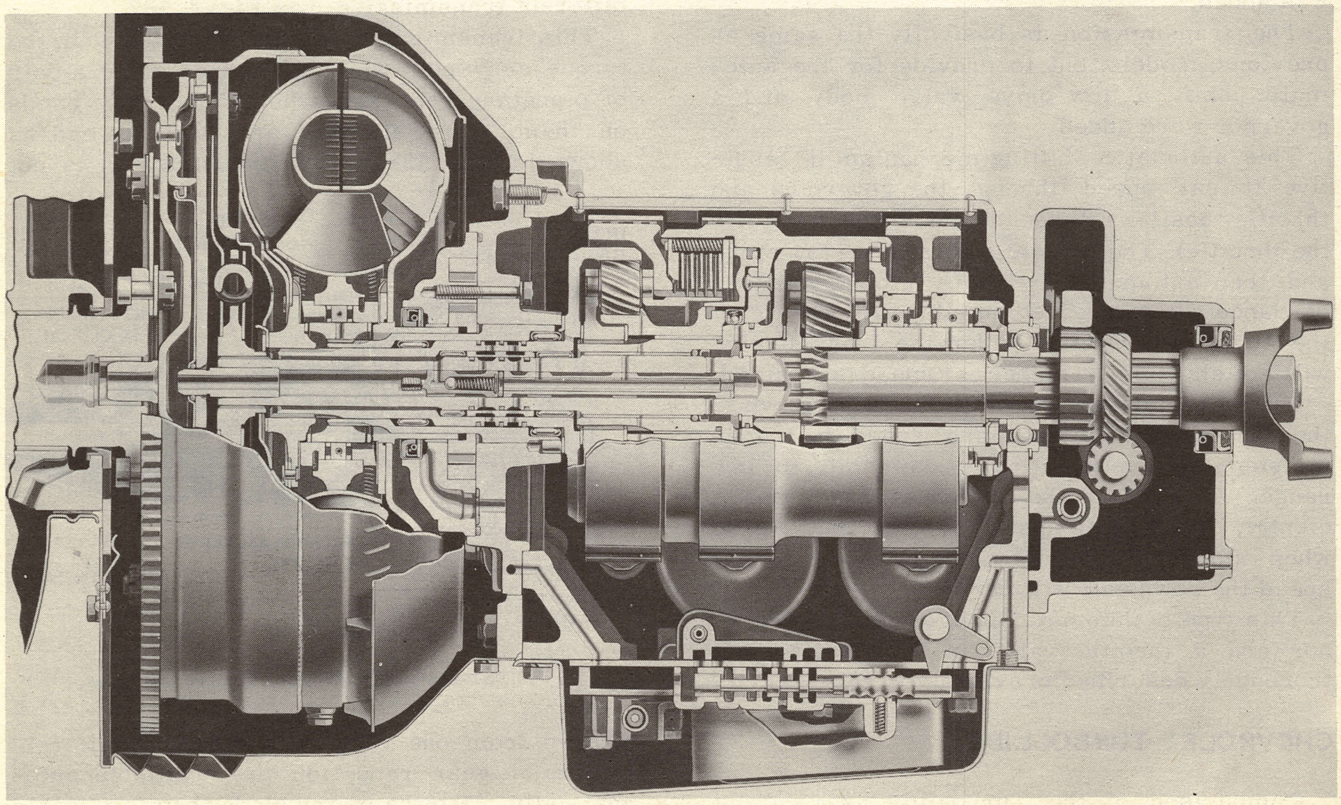
STUDEBAKER AUTOMATIC DRIVE

The Studebaker Automatic Transmission is of the air-cooled torque converter type and includes two planetary gear units. In design, it is quite similar to the Fordomatic previously described but the planetary gearing is hooked up somewhat differently. The complete unit is shown in partial cross-section in Fig. 45-40.

It will be noted that in addition to the pump, turbine and stator, it also has a positive drive clutch between the flywheel and torque converter in addition to the multiple disc clutch in

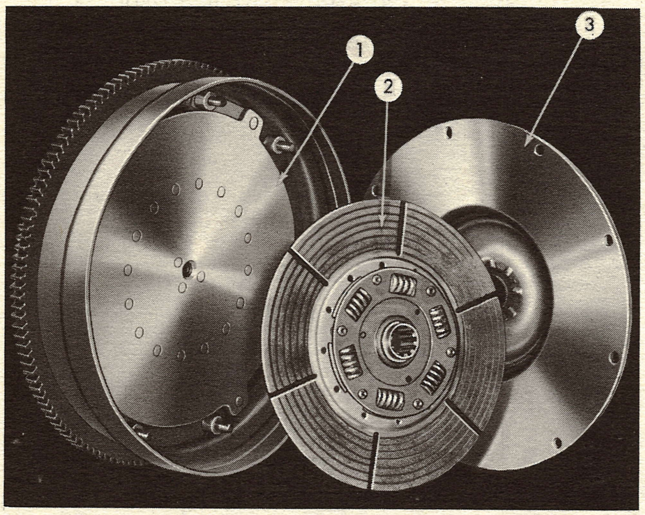


45-39. Variable pitch stator as used in Turboglide automatic transmission.



45-40. The Studebaker Automatic Transmission had a hydraulically controlled clutch between the engine and torque converter which provided a solid drive under certain conditions.

the planetary drum. See Fig. 45-41. The equipment includes a device to prevent "creeping" of the car when idling in high range and also a "hill holder" or device to prevent the car from rolling backward when stopped on a grade. These devices are both fully covered in the brake section of this book.



45-41. Elements of the Studebaker drive clutch were placed within the flywheel.

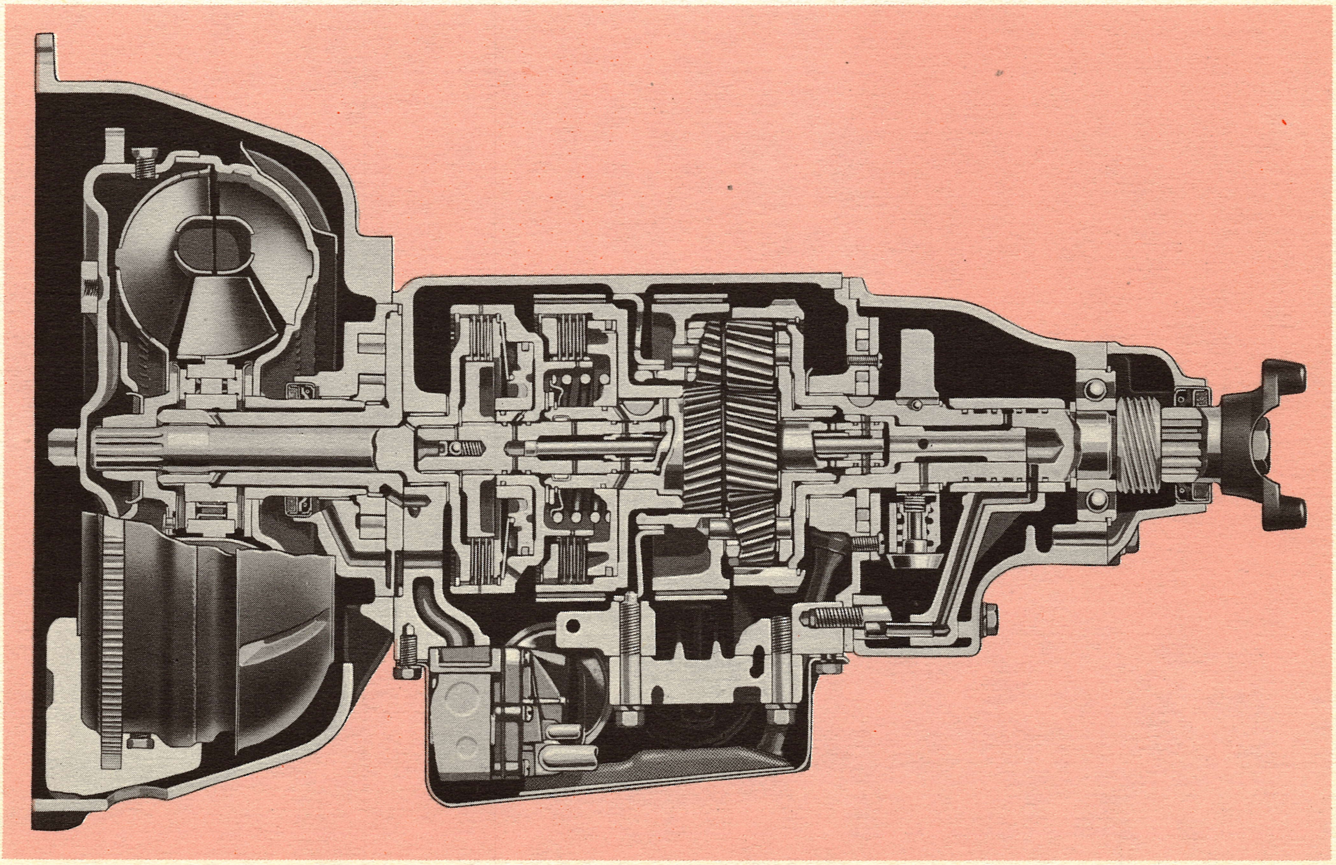
1956 FLIGHTOMATIC

While the Flightomatic is quite similar to and of the same manufacture as the previous Studebaker Automatic, it is not the same transmission. The positive drive clutch previously used has been omitted (See Fig. 45-42), and the planetary gears are arranged in different fashion.

QUIZ
TORQUE CONVERTERS

1. An automobile transmission torque converter may pump more than 50 barrels of oil per minute. True---, false---.
2. Does the spiral flow of oil in a torque converter increase the torque? Yes---, no---.
3. Does the velocity of the oil increase while it is going through the turbines? Yes---, no---.
4. Reversing the oil flow by means of stators is the method of increasing torque. True---, false---.
5. In the turbine, the oil flows away from the

45-42. The Studebaker Flightomatic dispensed with the solid drive feature.



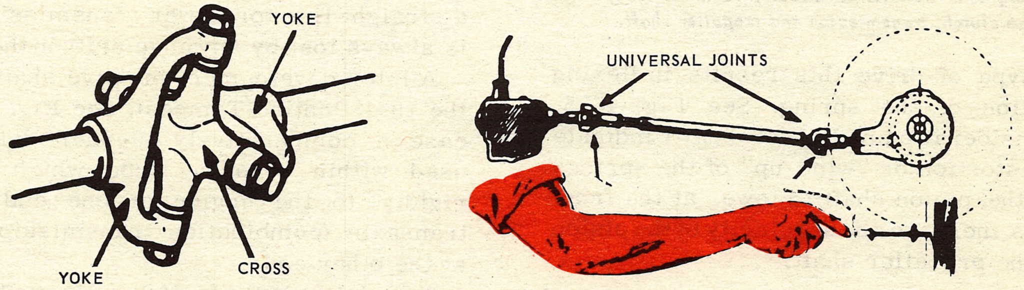
center due to the action of centrifugal force. True---, false---.

6. The stators do not turn in either direction. True---, false---.
7. Torque multiplication is greatest during acceleration. True---, false---.
8. Can the angle of stator blades be changed while the car is in motion? Yes---, no---.
9. Can more than one turbine be used in a single automatic transmission? Yes---, no---.
10. Multiple disc clutches are often used instead of drum bands in planetary gear sets. True---, false---.
11. The Chevrolet Powerglide transmission is somewhat similar to: the Fordomatic---, the Dynaflow---, the Flightomatic---.
12. The Chevrolet Turboglide is quite similar to the Chevrolet Powerglide. True---, false ---.
13. Both the Studebaker Automatic and the Flightomatic are similar to the Fordomatic. True---, false---.
14. Can a cone clutch be used instead of a disc clutch in an automatic transmission? Yes---, no---.

DRIVE LINE, UNIVERSAL JOINTS

DRIVE LINE

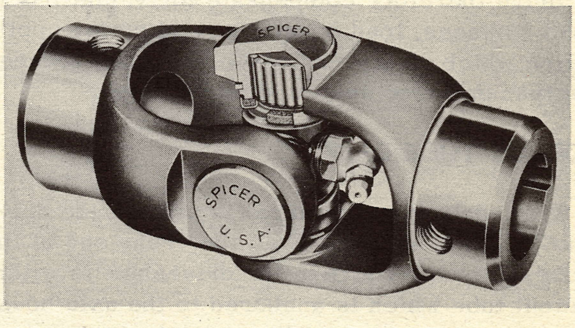
As the automobile engine is ordinarily mounted on the frame and the driving wheels are free to move up and down in relation to the frame, (within the limits of the suspension springs and linkage) it is necessary to have some sort of flexible drive system between the engine and drive wheels. Universal joints are ordinarily used for this purpose. See Figs. 46-1 and 46-2.



46-1. The yoke and cross in the Cardan type of universal joint permits angular movement. Universal joints function in a manner comparable with the elbow and wrist of a human forearm in combination.

UNIVERSAL JOINTS

While it would be desirable to have a straight line drive—that is, the propeller shaft in correct alignment with the engine crankshaft—this is not practical. The wheels move up and down due to road irregularities and the frame moves up and down in relation to the wheels, depending on the amount of weight in the automobile body. Therefore, a compromise is made and the design is intended to provide as nearly as possible a straight line under average conditions.



46-2. Anti-friction bearings are used on the cross journals of many universal joints and seals are provided to retain the lubricant.

TORQUE CHANGES

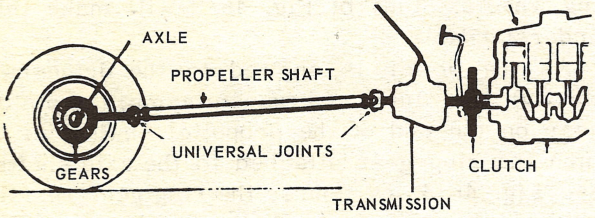
In addition to the changes brought about by wheel movement and load variations, there is a further change in angularity caused by the application of engine power. This comes about by the action of the torque developed in the driving wheels. Study of Fig. 46-3 will make this understandable.

As the power is applied to the driveshaft through the clutch and transmission, the pinion gear on the end of the propeller shaft tries to turn the ring gear attached to the axle shafts. See Fig. 46-4. Of course the ring gear resists movement as rotation of the wheels results in movement of the vehicle. The pinion would then roll around the ring gear if it were not held in place by the axle housing.

But the pinion is fastened securely to the axle housing and therefore the turning effort or torque is transferred to the axle housing. This torque effort is of considerable magnitude. This is indicated by the tendency of the front end of the car to rise when power is applied suddenly to the rear drive wheels. Perhaps the best example of this is a wheel type farm tractor pulling a plow in tough soil. At times the front wheels will almost get off the ground.

TORQUE TRANSFER

This powerful torque force is transferred from the pinion shaft to the axle housing and from the axle housing to the springs or to torque rods either of which are anchored to the frame. In the Hotchkiss type of drive this results in flexing and distortion of the spring. See Fig. 46-5. Further consideration of Fig. 46-3 will indicate that this distortion or "wind-up" of the springs will allow the pinion shaft to lower at the front end and thus increase the angularity of the pinion shaft with the propeller shaft.



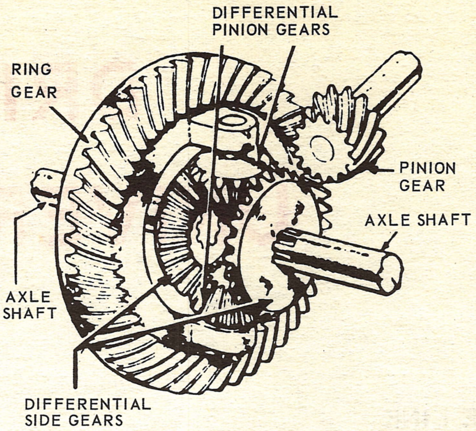
46-3. Engine torque is transferred directly to the drive pinion through the clutch, transmission and propeller shaft.

HOTCHKISS DRIVE

The two universal joints in the Hotchkiss type of drive therefore compensate for variations in road surfaces, load conditions and power application which cause changes in alignment between the transmission shaft and pinion shaft.

TORQUE TUBE DRIVE

When only one universal is used in the drive line the joint is placed at the front end of the driveshaft. In this case the driveshaft is within a stout tube which is anchored to the axle housing. See Fig. 46-6. This tube is known as a torque tube and it permits no twisting of the axle housing when the engine power is applied. The springs therefore do not absorb any torque and are required only to cushion the ride. The single universal joint at the front end compensates for all relative movement between driving axle and frame.



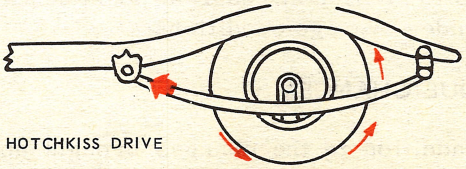
46-4. Being attached to the axle shafts, the ring gear resists the rotative effort of the pinion and the pinion then tends to roll around the ring gear.

With a torque tube drive the engine is usually mounted as low as possible in the frame or else mounted at an angle with the rear end lower than the front. Some Hotchkiss driven cars also have the engine tilted in the same manner. The object in either case is to obtain as nearly as possible a straight line for power transmission as power is always lost by any angularity in the drive line.

A later development in drive shafts is found in the 1961 Pontiac Tempest. See Fig. 46-7. In this case a comparatively slender drive shaft is used within a torque tube which is fastened rigidly to the engine at one end and to the transaxle (combination transmission and axle) at the other end.

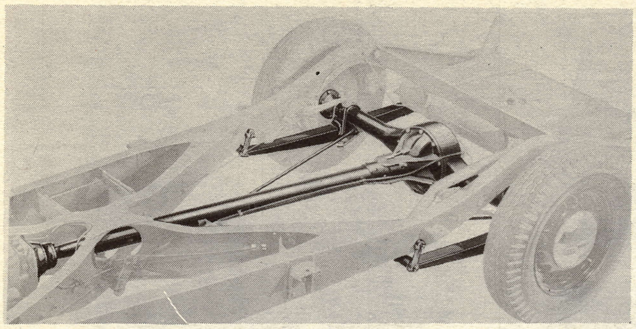
The driveshaft itself bends or flexes as required to compensate for relative movement between engine and axle. As the transaxle is mounted on the car frame, the relative movement is limited in scope. This driveshaft is made of heat-treated alloy and is shot peened on the surface to provide maximum resistance to fatigue. Vibration and whipping of the shaft is minimized by a rubber mounted ball bearing near the middle of the shaft.

As a matter of interest it should be noted at this time that when the Hotchkiss type of drive is used, the forward motion of the vehicle is caused by the front end of the rear springs



46-5. In the Hotchkiss type of drive, the spring is used to absorb the torque applied to the rear axle housing.

pushing against the frame. See Fig. 46-5. In the torque tube drive, the pushing action is at the front end of the torque tube. See Fig. 46-6.

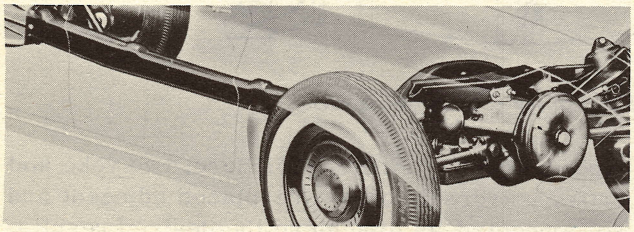


46-6. Where a torque tube is used, there is no torque applied to the rear springs.

PROPELLER SHAFT LENGTH

In addition to changes in angularity of the driveshaft as just described, we find that the distance between the transmission shaft and the pinion shaft is subject to change. This will require some flexibility in the length of the driveshaft. See Fig. 46-8.

In Fig. 46-8 (which illustrates a Hotchkiss type of drive) the front end of the propeller shaft is attached to the transmission shaft (B). The rear end of the propeller shaft is attached to the pinion shaft (C). As the wheels move up and down, the propeller shaft swings up and down in the arc (A-A) around pivot (B). At the same time the pinion shaft (C)—being attached to the rear axle—swings in an arc (D-D) around the pivot where the spring is anchored to the frame at (E). Therefore as the arcs (A-A) and (D-D) do not coincide, it will be necessary for the propeller shaft to alternately lengthen and shorten as the wheels move in relation to the frame.



46-7. A flexible driveshaft without universal joints is used within a rigid torque tube on the Pontiac Tempest.

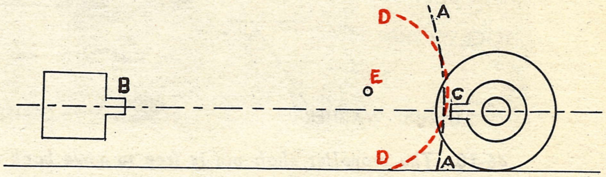
SLIP JOINTS

One method of doing this is to provide a splined shaft coupling or "slip joint" as shown in Fig. 46-9. Another method is shown in Fig. 46-10. This movement is less on a torque tube type of drive, but a slip joint is used at the one joint.

When the type of slip joint shown in Fig. 46-9 is used it is possible to assemble it incorrectly. They often are assembled incorrectly and the result is annoying vibration. Such joints are usually marked for correct assembly as shown in Fig. 46-11. If they are not marked it is only necessary to make sure that both yokes are in the same plane as shown in Fig. 46-12.

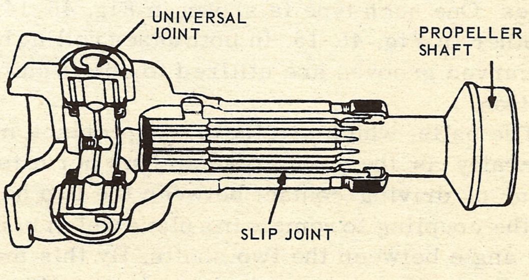
VARYING SHAFT SPEEDS

When the yokes at each end are "out of phase," that is, not in the same plane, the rotational speed of the driven shaft will not be uniform when operating at an angle. If operated in a straight line the rotational speed of the driving shaft, the propeller shaft, and the driven shaft would be uniform.



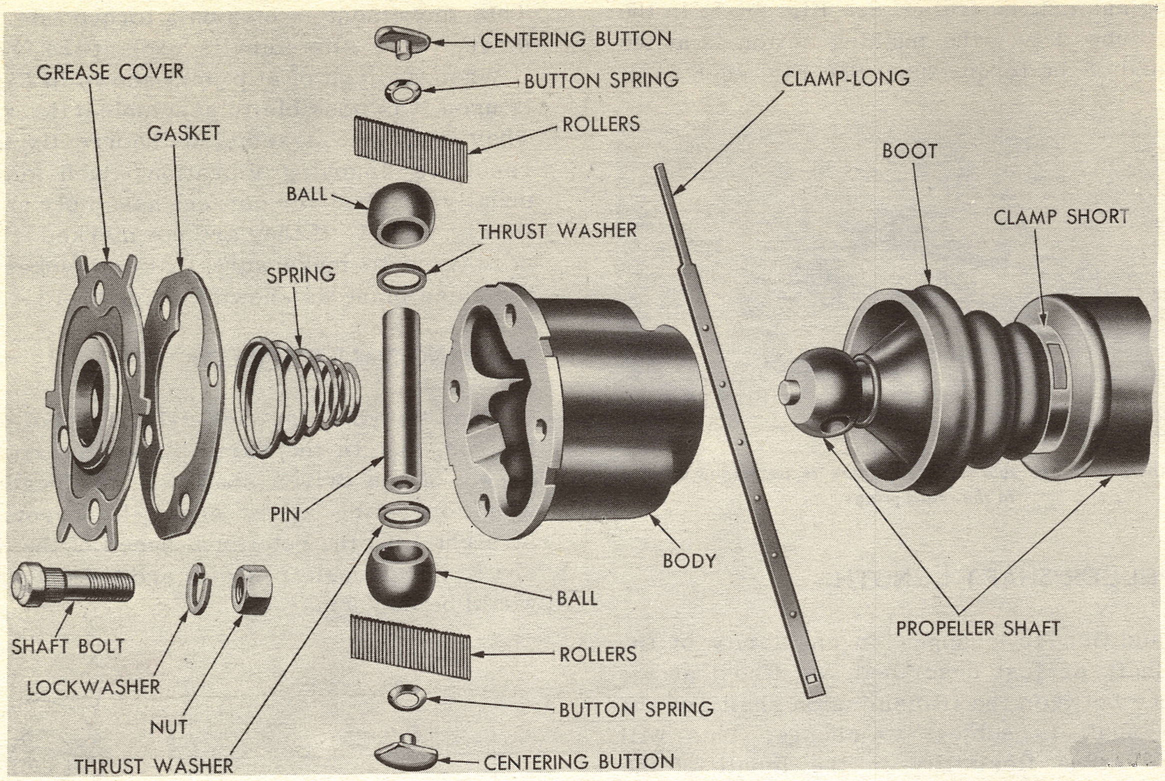
46-8. Variations in the length of the driveshaft occur in the Hotchkiss type of drive as the wheels move up and down because of the changes in wheel base length as described in the text.

When operating at an angle, the conventional joint will cause the driven shaft to speed up and slow down twice each revolution. This is shown in Fig. 46-13. The NUMBER OF TURNS will be the same but the VELOCITY or speed of rotation of the driven shaft will fluctuate. When the two yokes of a propeller shaft are in phase, the speed of the transmission shaft and the pinion shaft will be constant and the same if the angles of both shafts are uniform. The VELOCITY of the connecting propeller shaft will not be constant, but this is unimportant as long as the velocity of the driving and driven shafts is uniform.

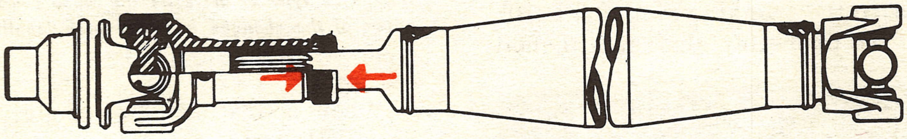


46-9. The splined end of the propeller shaft is free to slide endwise within the splines of the universal joint.

Sometimes it is desired to drive and steer with


CENTERING BUTTON
BUTTON SPRING
ROLLERS
GREASE COVER
GASKET
CLAMP-LONG
BOOT
BALL
THRUST WASHER
CLAMP SHORT
SPRING
PIN
BODY
BALL
SHAFT BOLT
LOCKWASHER
NUT
THRUST WASHER
ROLLERS
BUTTON SPRING
CENTERING BUTTON
PROPELLER SHAFT

46-10. The propeller shaft pin is free to move back and forth in the channels of the universal joint body to allow for variations in drive line length.



46-11. The splined shaft should be inserted so that the arrows align as shown.

the same wheels and use only one universal joint at each wheel as in front drive cars and all-wheel drive trucks. The lack of uniform velocity while the wheels are turned at a considerable angle for steering would present a serious problem.

CONSTANT VELOCITY JOINTS

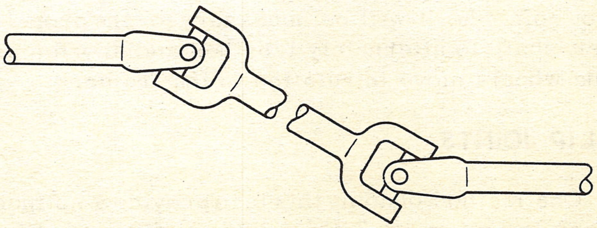
This problem led to the development of special universal joints known as "constant velocity" types. One such type is shown in Fig. 46-14 and another in Fig. 46-15. In both cases rolling balls in curved grooves are utilized to obtain uniform motion.

The balls, which are the driving contact, move laterally as the joint rotates. This permits the point of driving contact between the two halves of the coupling to remain in a plane which bisects the angle between the two shafts. By this means the fluctuation in speed shown in Fig. 46-13 is avoided.

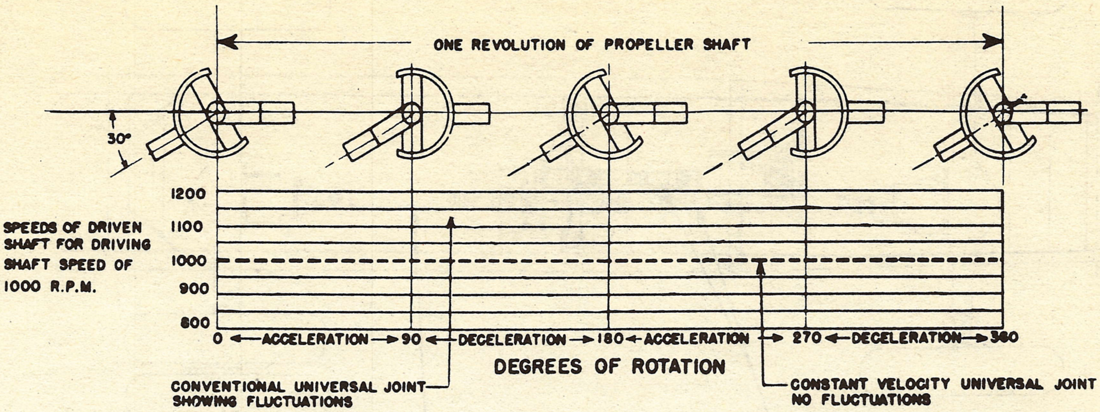
A later development of the constant velocity type is shown in Fig. 46-16. Here, two yoke and cross universal joints are placed adjacent and so connected as to achieve the desired results.

TRANSFER CASES

When a vehicle is driven by both front and rear wheels, it is necessary to provide a sort of power take-off to drive both axles. Such an arrangement is shown in Fig. 46-17. This auxiliary device is known as a transfer case. The details of a typical transfer case are shown in Fig. 46-18. It is cus-



46-12. The yokes should always be in the same plane.



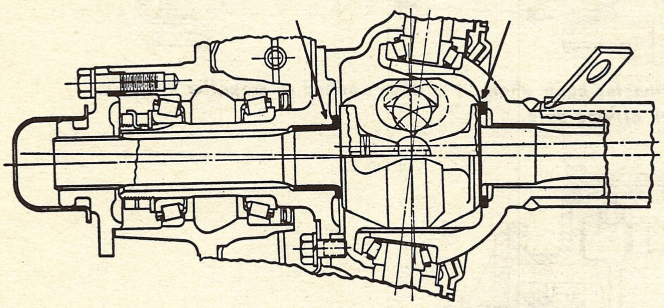
CONVENTIONAL UNIVERSAL JOINT

SHAFT ANGLE IN DEGREES	8	10	15	20	25	30	40
MAXIMUM VARIATION IN DRIVEN SHAFT SPEED PERCENT	2	3	6.9	12.4	19.7	28.9	54

46-13. This chart shows the variation of speed in the driven shaft using a Cardan joint operated at various angles.

tomary to provide a shifting device on such units so that the front drive can be disconnected if desired.

As the angularity of the driveshafts between front and rear wheels changes constantly, the transfer case is positioned in the best possible compromise to serve both axles. Reference to Fig. 46-17 will also indicate that each propeller shaft is fitted with a slip joint to accommodate changes in distance between axles and transfer case as the wheels move up and down.



46-14. Constant velocity type of universal joint as made by Bendix.

CENTER BEARINGS

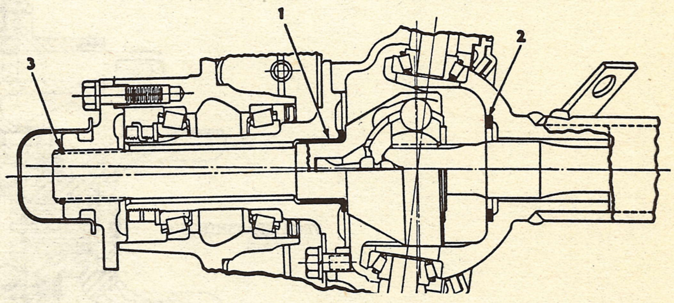
In exceedingly long trucks and quite often in passenger automobiles, the propeller shaft is divided into two lengths and a supporting "center bearing" is inserted. See Fig. 46-19. The details of a typical supporting bearing are shown in Fig. 46-20.

Such bearings are used to stabilize the shaft and reduce vibration and "whip." Propeller shafts rotate at engine speed and are liable to whip or bend at high speed. This whip comes about from the action of centrifugal force aided by any unbalance that may exist in the shaft. For this reason propeller shafts are carefully balanced.

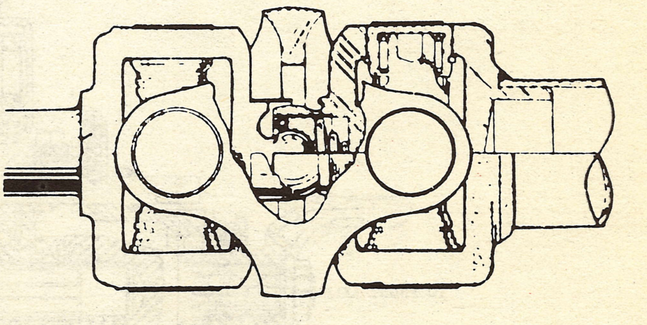
DIFFERENTIALS AND AXLES

Early automobiles were driven by means of belts or ropes around pulleys mounted on the driving wheels and engine shaft or transmission shaft. As there was always some slippage of the belts, one wheel could rotate faster than the other when turning a corner.

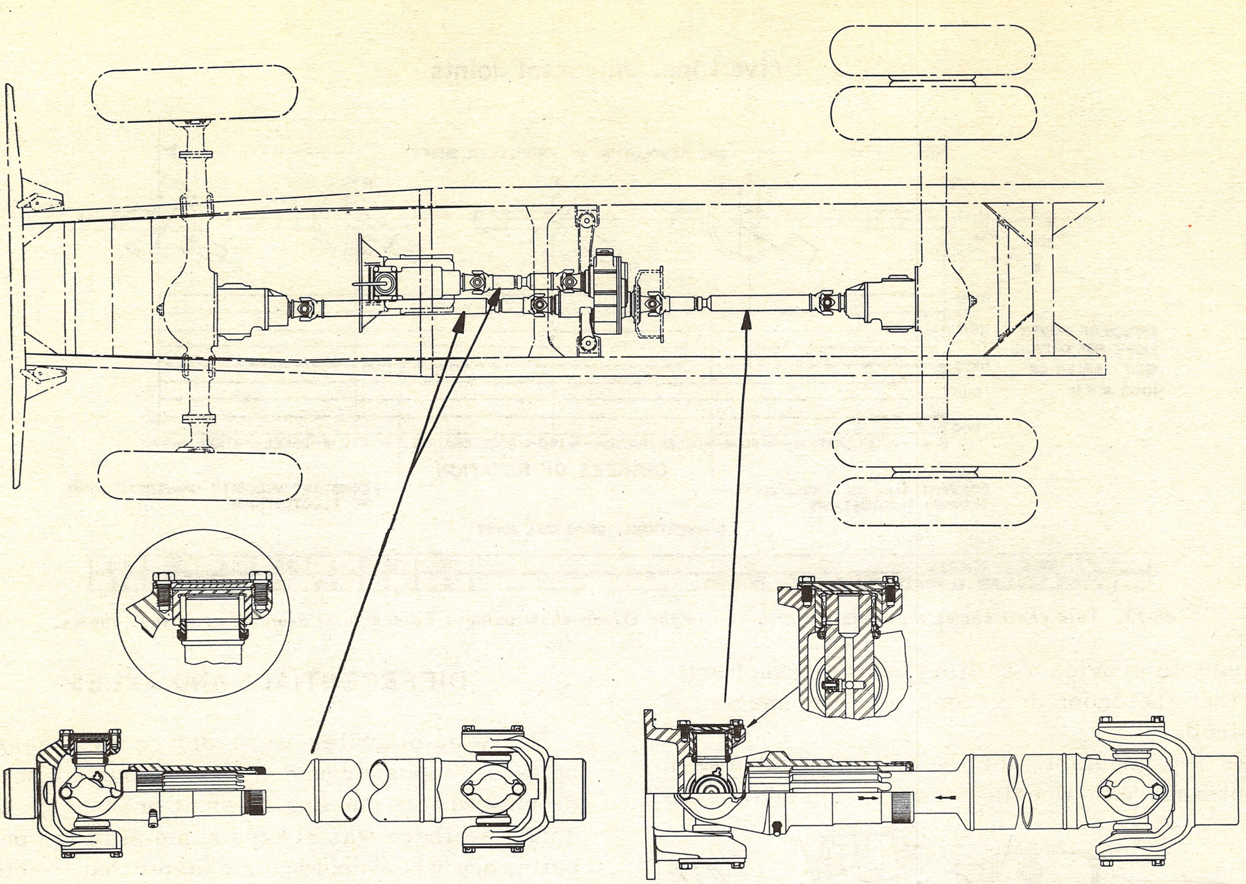
When belts proved unsatisfactory, the builders borrowed an idea from the bicycle and applied sprockets and chains. As this was a positive driving arrangement it was necessary to provide differential gearing to permit one drive wheel to turn faster than the other. Such an arrangement is shown diagramatically in Fig. 46-21.



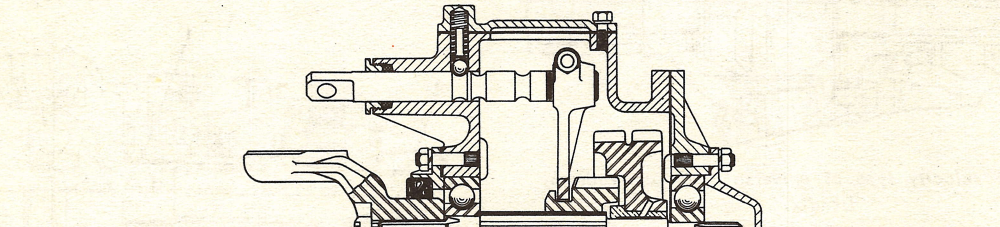
46-15. Another type of constant velocity universal joint known as the Rzeppa.



46-16. Two yoke and cross type universal joints as combined to transmit constant velocity.



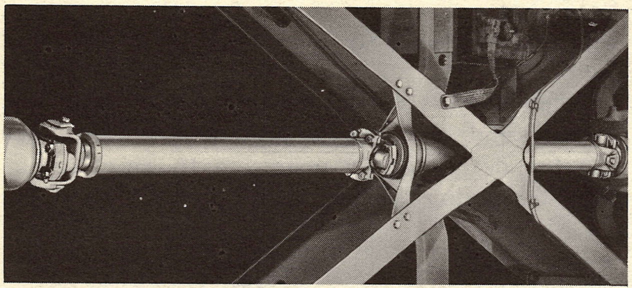
46-17. *The engine torque goes from the transmission to a transfer case where it is then applied to propeller shafts extending to each driving axle.*


FROM TRANSMISSION
TO FRONT AXLE
TO REAR AXLE

46-18. *This cross-section of a transfer case shows the gears and shafts which divide the torque between the driving axles.*

DIFFERENTIAL GEARS

In this differential gear arrangement, which is shown in more detail in Fig. 46-22, the pinion gear is turned by the engine. This rotates the ring gear to which is attached the differential housing on which the differential pinion gears are mounted. These differential pinion gears mesh with the differential side gears which are attached to the axle shafts. This completes the link from power source to driving wheels.



46-19. Extra long propeller shafts are often fitted with a center bearing support mounted on the frame.

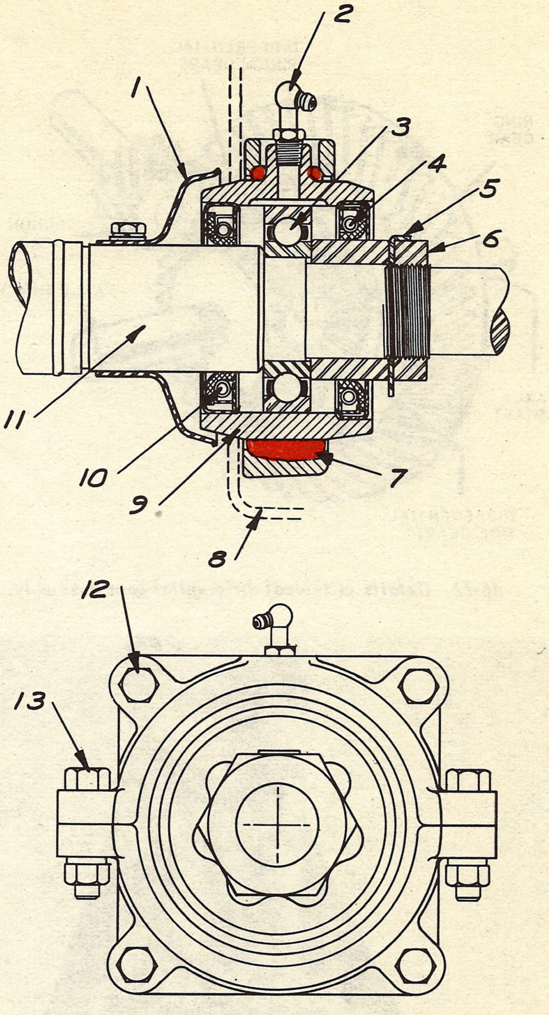
Consideration of Figs. 46-21 and 46-22 will indicate that as the pinion gear rotates, the ring gear and differential pinion gears will rotate with the housing attached to the ring gear. The pinion gears will not tend to turn or rotate about their own axis, however. They will apply an equal amount of effort to each of the differential side gears and axle shafts.

If now, however, the resistance toward rotation of either axle increases or decreases---as in turning a corner or one tire being upon a slippery surface---the differential pinion gears will tend to turn around their own axis. The result of this tendency will be for the differential pinion gear to roll around the differential side gear on the reluctant one of the two axles.

This action allows the reluctant axle to slow down or stand still and causes a corresponding increase in the speed of rotation of the other axle. If one axle does not turn at all, the other axle will turn at almost twice the normal speed. Thus it is possible for the drive wheels to turn at unequal speeds while the same amount of power is applied to both of them.

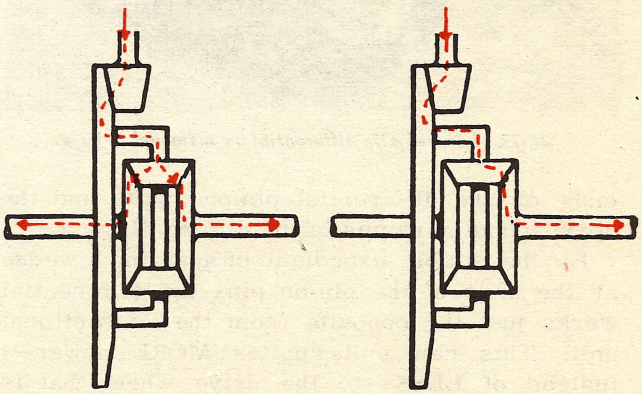
LIMITED SLIP DIFFERENTIALS

Used by a number of different makes of automobiles and known under several different names, the construction of these devices is similar. Some use cone clutches and others use disc clutches. The design is identified by the beveled

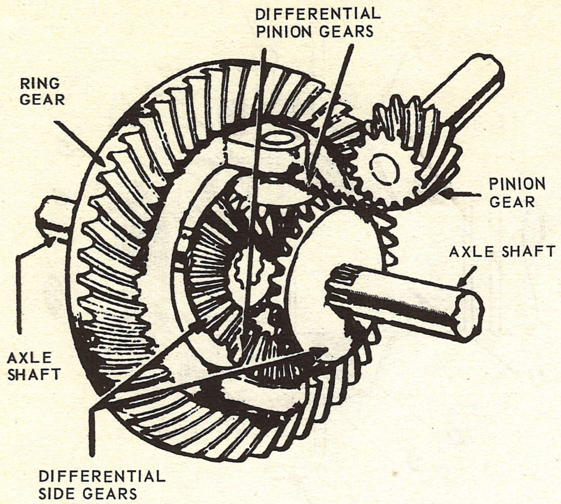


1. Dust shield
2. Lubricator
3. Bearing
4. Rear oil seal
5. Lock washer
6. Retaining nut
7. Insulator
8. Cross frame
9. Housing for center bearing
10. Front oil seal
11. Forward drive shaft
12. Bolts
13. Clamp bolts

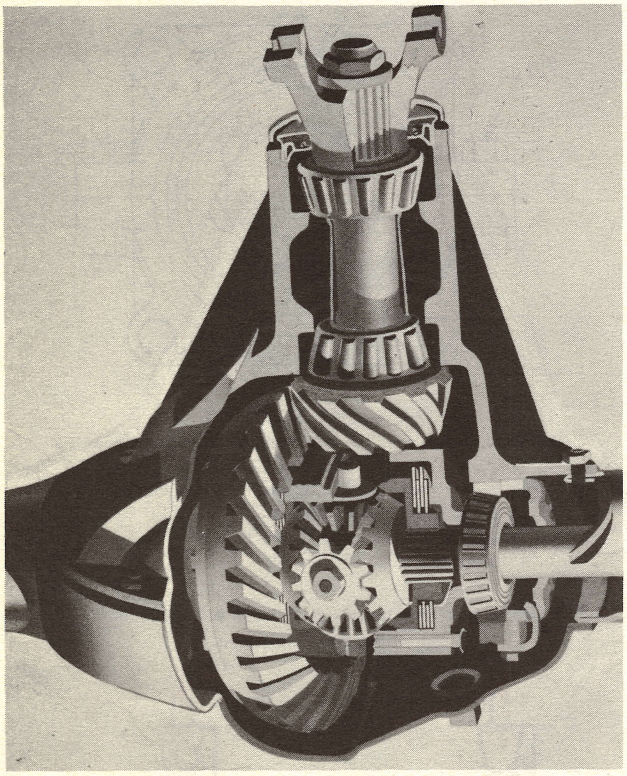
46-20. Center bearings are usually mounted in rubber to insulate them from the frame.



46-21. Differential gearing shown in diagrammatical form to indicate flow of power.


DIFFERENTIAL PINION GEARS
RING GEAR
PINION GEAR
AXLE SHAFT
AXLE SHAFT
DIFFERENTIAL SIDE GEARS

46-22. Details of typical differential gear assembly.



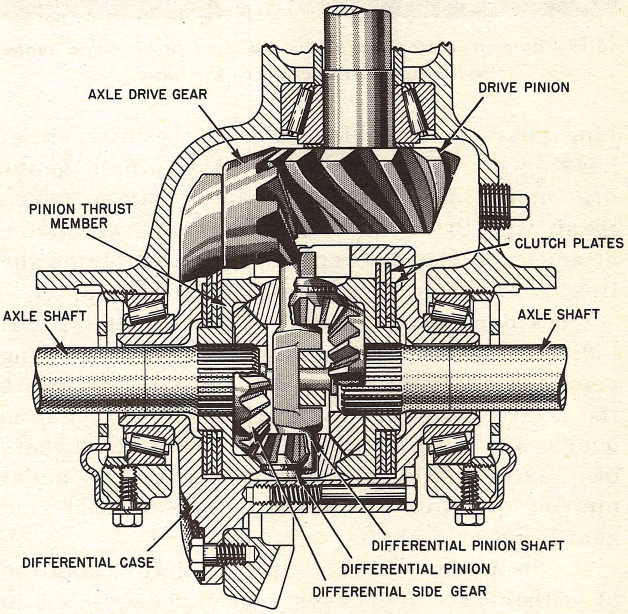
46-23. Limited slip differential as installed in axle.

ends on the differential pinion shafts and the corresponding ramps in the differential case.

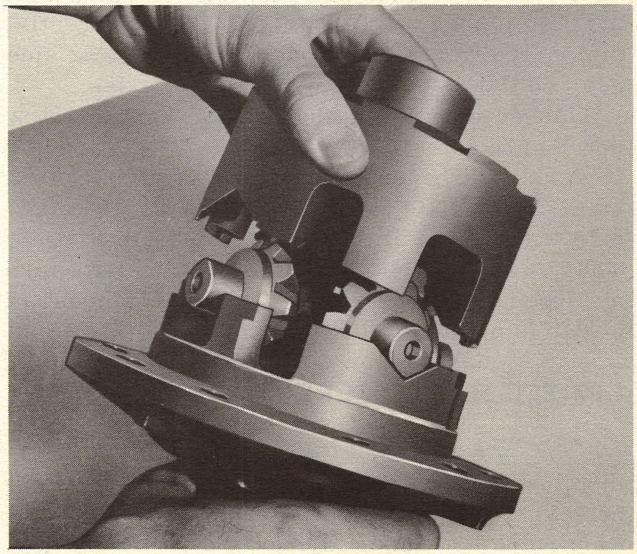
By the simple expedient of applying a wedge at the ends of the pinion pins the differential works just the opposite from the conventional unit. This new unit applies MORE power---instead of LESS---to the drive wheel that is harder to turn.

This differential is shown in Figs. 46-23 and 46-24. The construction is such that the differential pinion and pinion shafts float between the differential gears on the ends of the axle shafts. Also a clutch is inserted on each side between the differential gears and the differential case. The pinion shaft ends are partially angular in shape as shown in Fig. 46-25 and contact corresponding ramps in the differential housing. Note that one pair of ramps face the ring gear, while the other pair face away from the ring gear.

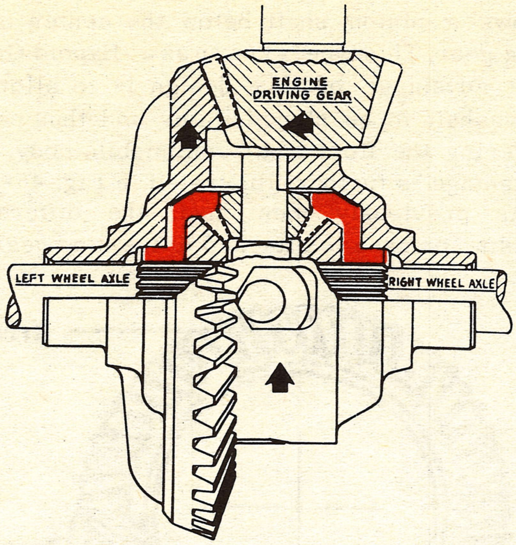
When power is applied to the ring gear, the ramps tend to force the side differential gears apart and thus apply pressure to the clutch on the side having the best traction. See Fig. 46-26.


AXLE DRIVE GEAR
DRIVE PINION
PINION THRUST MEMBER
CLUTCH PLATES
AXLE SHAFT
AXLE SHAFT
DIFFERENTIAL PINION SHAFT
DIFFERENTIAL CASE
DIFFERENTIAL PINION
DIFFERENTIAL SIDE GEAR

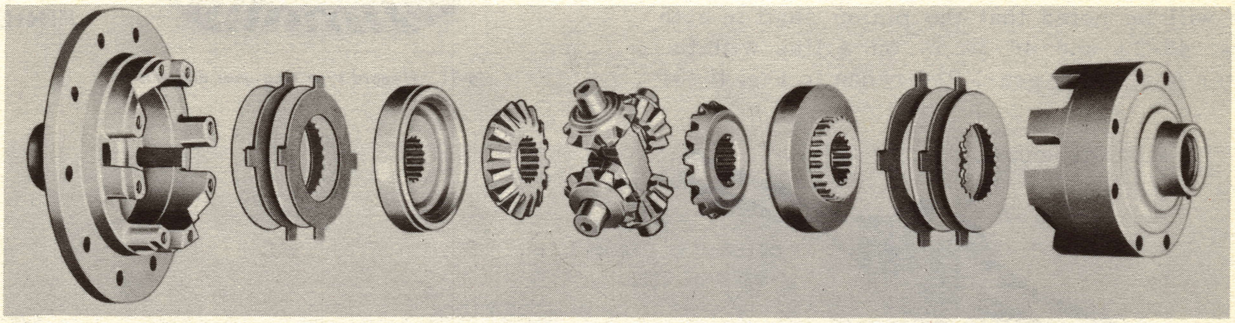
46-24. Cross section of limited slip differential.



46-25. Ramps in differential housing face in opposite directions.



46-26. This model uses a cone type of clutch between the gear backs and the inside of the differential case.

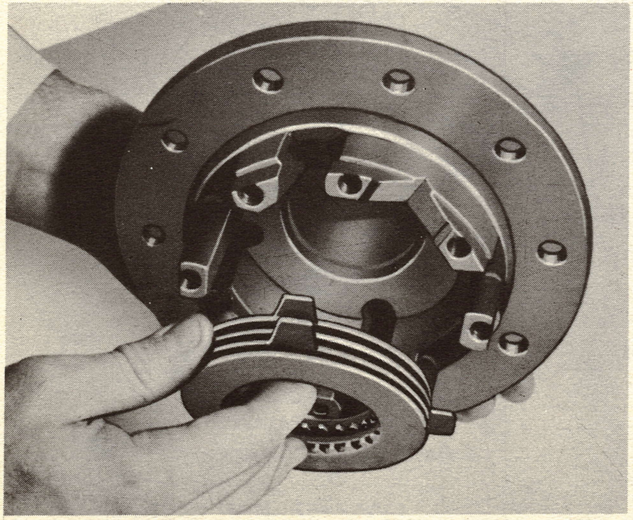


46-27. Instead of cone clutches, disc clutches may be used.

At the same time the wheel that tends to slip has less power applied to it and therefore better traction is obtained for both drive wheels.

In those installations using the multiple disc type of clutch, the amount of slippage can be altered by the disc installation. If assembled alternately as shown in Fig. 46-28 maximum friction is obtained. If the two inner discs are installed between the two outer discs the friction is reduced.

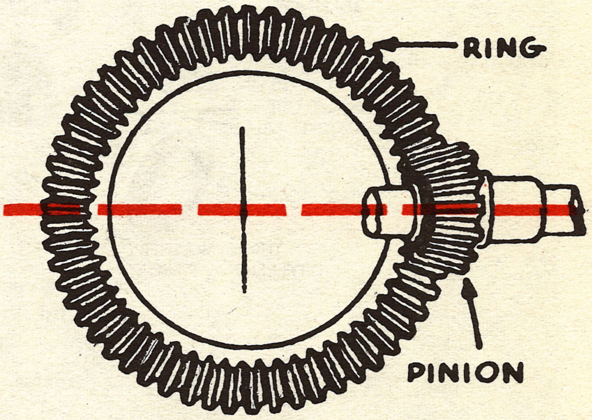
It should be obvious that any car equipped with this device must have BOTH drive wheels jacked up off the floor if any attempt is made to run the engine with the transmission in operation. Serious damage could occur if the car should thus move unexpectedly.



46-28. Alternate method of assembling clutch discs to obtain maximum friction.

BEVEL GEARS

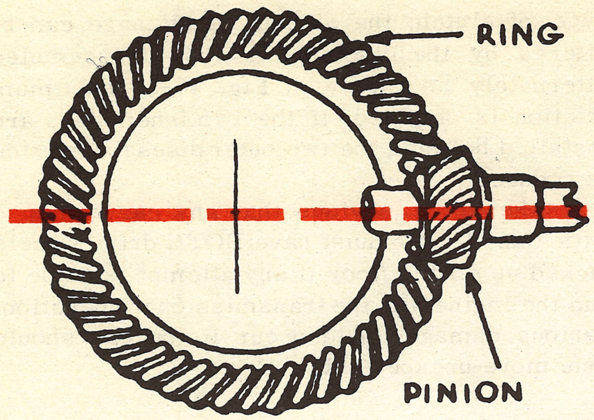
Pinion and ring gears have different tooth designs. The original type was known as a "straight bevel." The teeth were straight like a spur gear as shown in Fig. 46-29.



46-29. Straight bevel ring gear and pinion.

SPIRAL BEVEL GEARS

Another type is known as a "spiral bevel." In this case the teeth are curved as shown in Fig. 46-30. The spiral bevel is much quieter in use than the straight bevel as the teeth have a sliding


RING
PINION

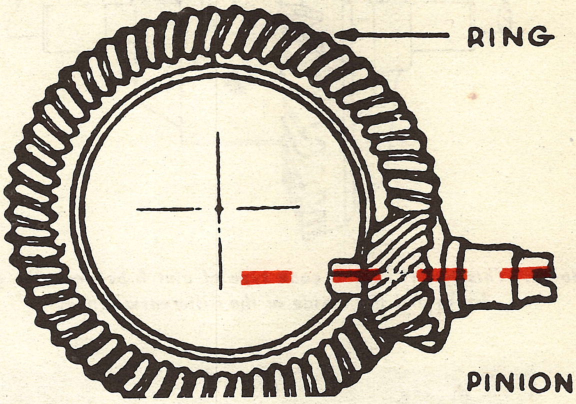
46-30. Spiral bevel ring gear and pinion.

contact. They are also stronger as more than one tooth is in contact at all times.

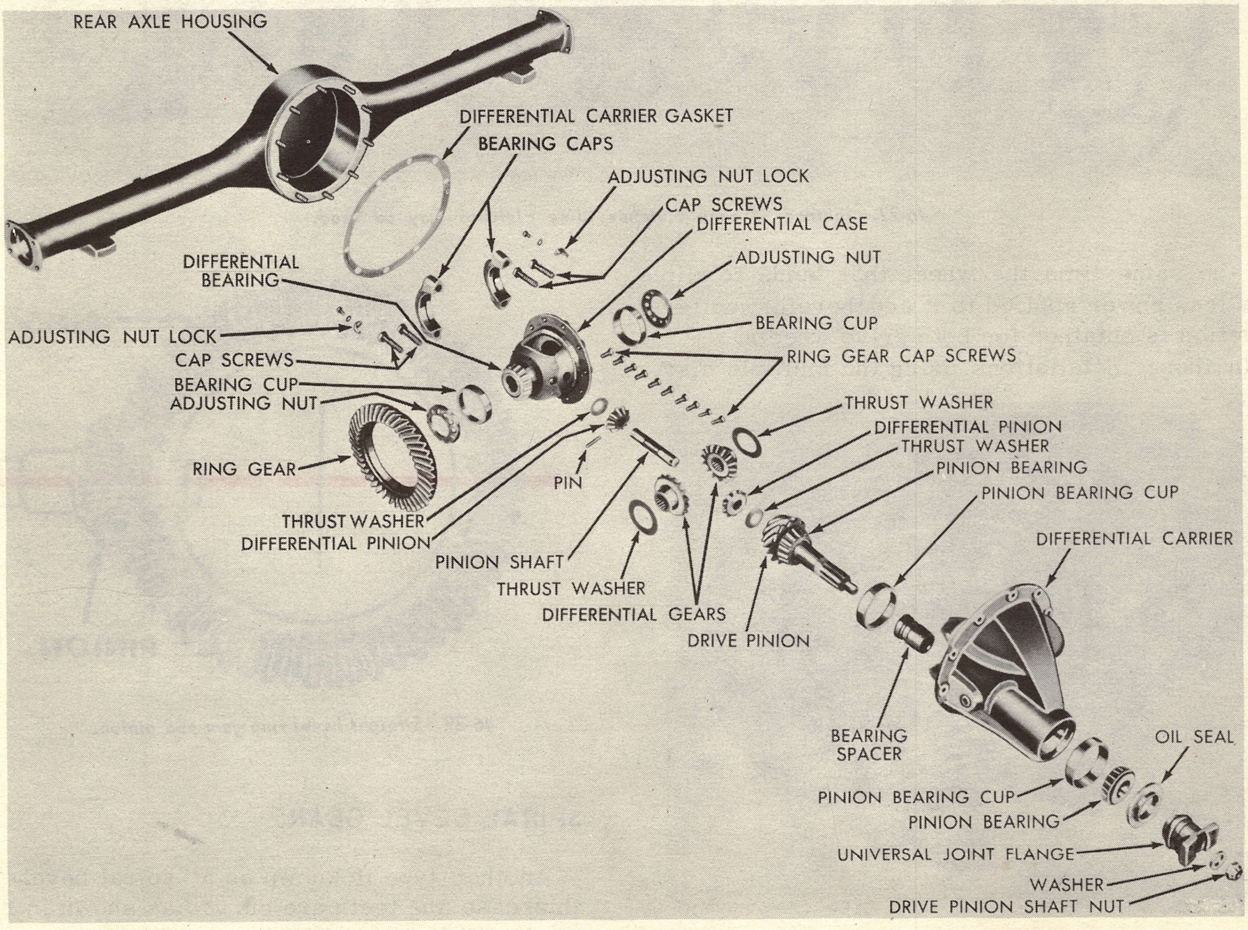
HYPOID GEARS

It will be noted that the pinion shaft in both Figs. 46-29 and 46-30 is on a line with the center of the ring gear. Reference to Fig. 46-31 shows a pinion shaft below the center of the ring gear. This type is known as a "Hypoid Gear." The advantage of this design is to allow the driveshaft to be placed lower and thus permit lowering the floor of the automobile body. This advantage is further illustrated in Fig. 46-32.

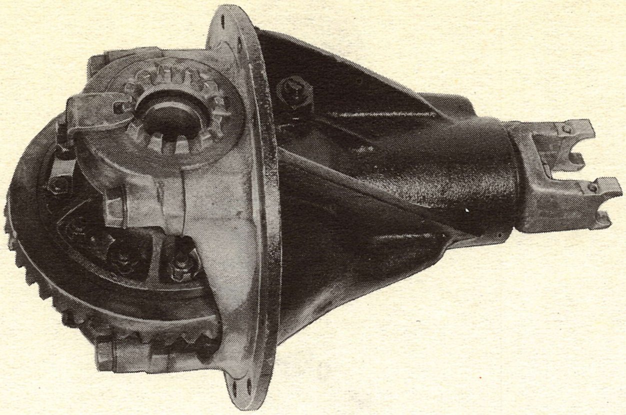
As previously mentioned, the differential housing or case is attached to the ring gear. As


RING
PINION

46-31. Hypoid type ring gear and pinion.


REAR AXLE HOUSING
DIFFERENTIAL CARRIER GASKET
BEARING CAPS
ADJUSTING NUT LOCK
CAP SCREWS
DIFFERENTIAL CASE
ADJUSTING NUT
DIFFERENTIAL BEARING
BEARING CUP
ADJUSTING NUT LOCK
CAP SCREWS
BEARING CUP
ADJUSTING NUT
RING GEAR CAP SCREWS
THRUST WASHER
DIFFERENTIAL PINION
THRUST WASHER
PINION BEARING
RING GEAR
PIN
PINION BEARING CUP
DIFFERENTIAL CARRIER
THRUST WASHER
DIFFERENTIAL PINION
PINION SHAFT
THRUST WASHER
DIFFERENTIAL GEARS
DRIVE PINION
BEARING SPACER
OIL SEAL
PINION BEARING CUP
PINION BEARING
UNIVERSAL JOINT FLANGE
WASHER
DRIVE PINION SHAFT NUT

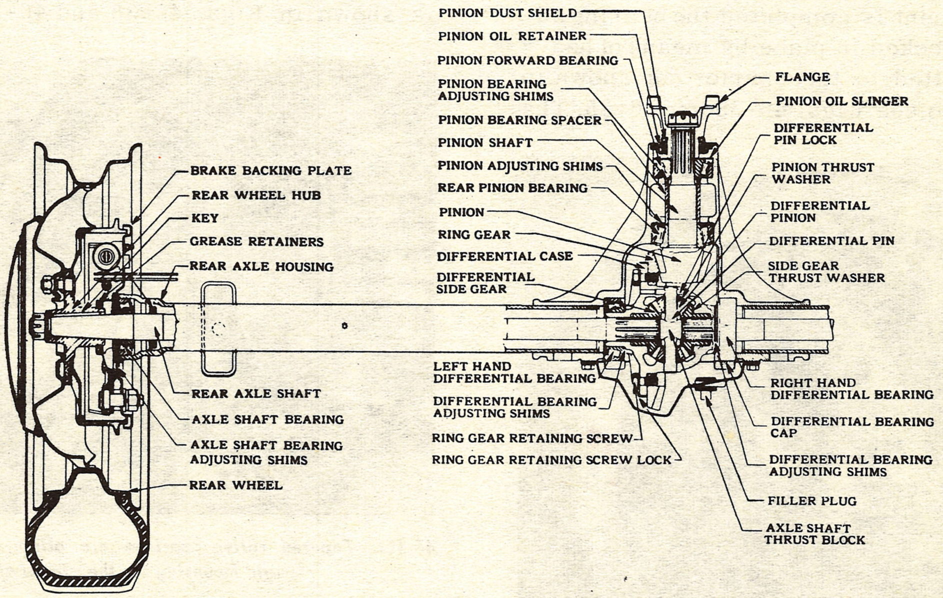
46-32. This exploded view of a complete rear axle assembly shows how the pinion is below the center of differential carrier.



46-33. In this case the entire differential assembly is mounted on a differential carrier which is bolted to the axle housing.

the entire propelling force is transmitted through this attachment, it must be a tight union. Several methods are used. One is cold riveting and consists of inserting iron rivets through matching holes in the ring gear and differential case. Another method is hot riveting, and still another is bolts or capscrews.

Whatever the method used, it is essential that the holes match exactly, that the size of the holes be accurate, and that the rivets or bolts fill the holes tightly.


PINION DUST SHIELD
PINION OIL RETAINER
PINION FORWARD BEARING
PINION BEARING ADJUSTING SHIMS
PINION BEARING SPACER
PINION SHAFT
PINION ADJUSTING SHIMS
REAR PINION BEARING
PINION
RING GEAR
DIFFERENTIAL CASE
DIFFERENTIAL SIDE GEAR
FLANGE
PINION OIL SLINGER
DIFFERENTIAL PIN LOCK
PINION THRUST WASHER
DIFFERENTIAL PINION
DIFFERENTIAL PIN
SIDE GEAR THRUST WASHER
BRAKE BACKING PLATE
REAR WHEEL HUB
KEY
GREASE RETAINERS
REAR AXLE HOUSING
REAR AXLE SHAFT
AXLE SHAFT BEARING
AXLE SHAFT BEARING ADJUSTING SHIMS
REAR WHEEL
LEFT HAND DIFFERENTIAL BEARING
DIFFERENTIAL BEARING ADJUSTING SHIMS
RING GEAR RETAINING SCREW
RING GEAR RETAINING SCREW LOCK
RIGHT HAND DIFFERENTIAL BEARING
DIFFERENTIAL BEARING CAP
DIFFERENTIAL BEARING ADJUSTING SHIMS
FILLER PLUG
AXLE SHAFT THRUST BLOCK

46-34. In this case the differential assembly is mounted in the rear axle housing.

BOLT ATTACHMENT

If the ring gear is bolted to the case, it is necessary to have an excellent fit between the bolts and the holes. The usual procedure is to machine the bolt to accurate diameter, then drill the holes and ream them to correct size for a tight fit. The nuts on the bolts are then drawn up tightly and securely locked.

In case the attaching means is to be capscrews, the holes in the ring gear are threaded before the gear is hardened. The threads on the capscrew do not extend into the holes in the differential case, and the capscrew often has a shoulder between the threads and the head. This shoulder is finished to a size that fits tightly in the holes in the differential case.

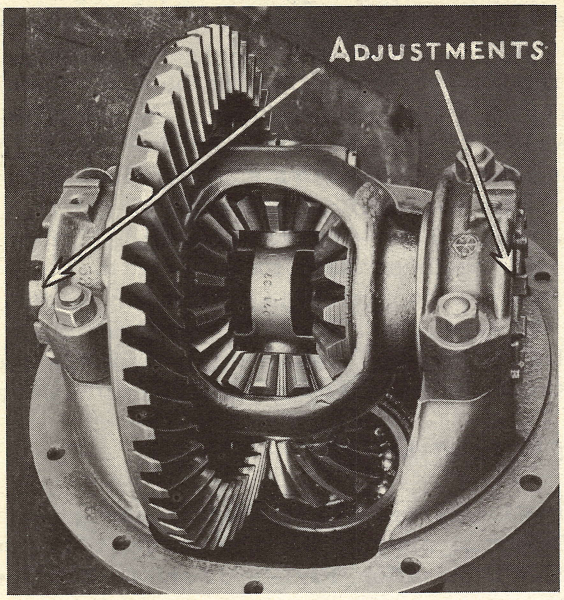
It is customary to drill a small hole through the bolt heads so that a locking wire may be run around the bolt circle to prevent any loosening of the capscrews. Furthermore, if one of these bolts should come loose and fall out, it might get between the gears and ruin the entire differential.

DIFFERENTIAL UNIT

Passenger car differentials ordinarily use two differential pinions on a straight shaft. The exploded illustration, Fig. 46-32 shows the differential case and gears. Heavy duty differentials as used on trucks often have a four pinion differential gearing.

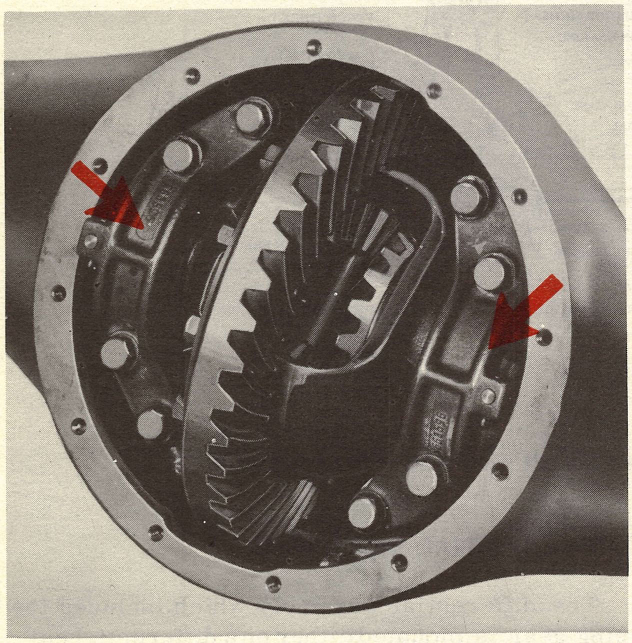
DIFFERENTIAL MOUNTING

The differential assembly which includes the ring gear is mounted either on a differential carrier as shown in Fig. 46-33 or else it is mounted directly in the rear axle housing as shown in Fig. 46-34. In all cases there is a bearing on each side of the assembly which provides a means of adjustment to move the ring gear toward or away from the pinion gear. See Fig. 46-35.

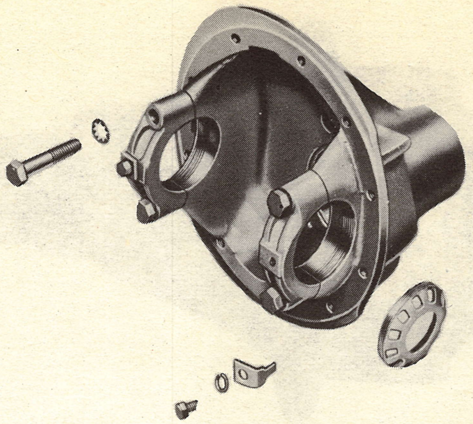


46-35. Rigid adjustable bearings are provided on each side of the ring gear and differential assembly.

When adjustment is completed the bearing adjustments are locked in place by means of heavy saddles and bolted to the carrier as shown in Fig. 46-36. Also see Figs. 46-33 and 46-35. The retaining bolts or screws are made secure by lock washers or by wiring. Details of each part are shown in Fig. 46-37.



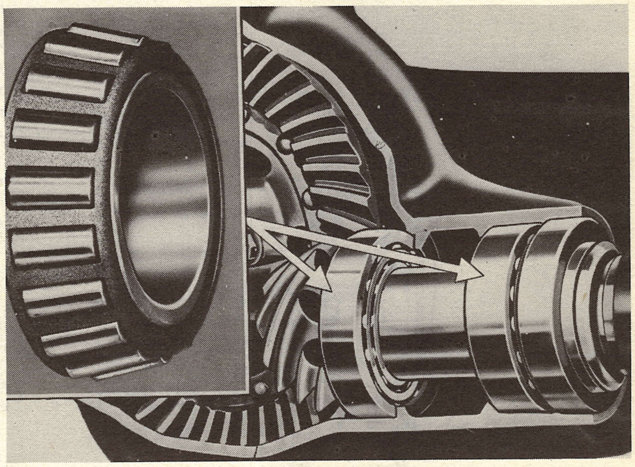
46-36. The bearing adjustments are secured by heavy saddles bolted in place after adjustment is completed.



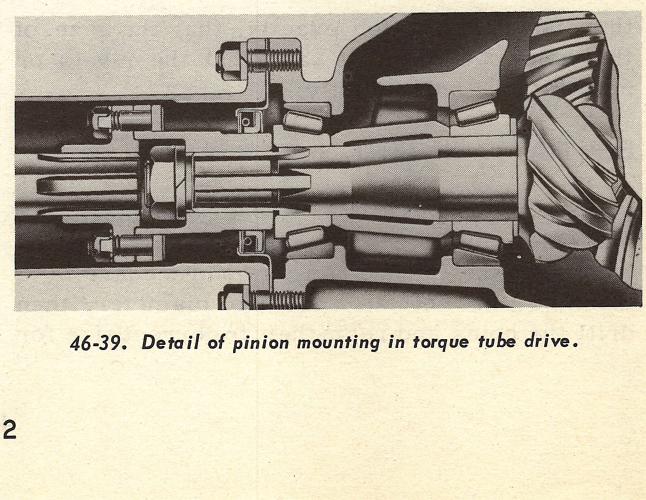
46-37. Details of adjusting rings, retaining saddles and adjustment locks.

PINION MOUNTING

The pinion which meshes with the ring gear is also mounted on bearings in the pinion carrier or axle housing as shown in Fig. 46-38. If the torque tube type of drive is used, the mounting is quite similar as shown in Fig. 46-39. Instead of using a pair of opposed tapered roller bearings as shown in Figs. 46-38 and 46-39, some con-



46-38. Tapered roller bearings are often used to provide a rigid mounting for the pinion shaft.

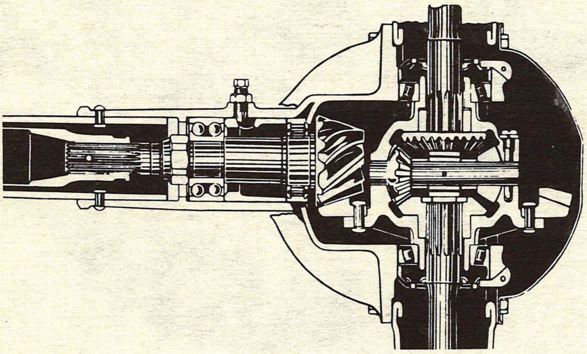


46-39. Detail of pinion mounting in torque tube drive.

structions consist of a roller bearing and a ball bearing as shown in Fig. 46-40.

THRUST LOADS

Whatever the construction, the bearings must prevent any endwise motion of the pinion shaft. In the case of the opposed angular roller bearings, the bearings themselves handle both radial and thrust loads. In the case of the ball bearing shown in Fig. 46-40, the ball bearing is a combination radial and thrust design.



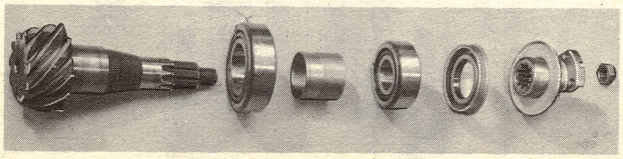
46-40. In this case a roller bearing is used in combination with a double row radial and thrust ball bearing to mount the pinion shaft.

BEARING PRE-LOADING

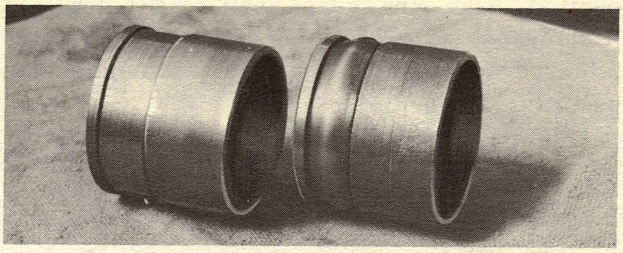
The necessity to avoid endwise motion is indicated by the instructions issued by many car manufacturers to "pre-load" these bearings. By pre-loading is meant to place the bearings under a slight tension. In some cases this is done by SLIGHT overtightening of the bearing adjustments. In other cases it is accomplished by the use of a special bearing spacer or sleeve.

Such a sleeve is shown in the pinion and bearing assembly in Fig. 46-41. The sleeve between the two bearings is made with a weakened section. After installation, the bearings are pulled together until the sleeve distorts. A new sleeve and a distorted sleeve are shown in Fig. 46-42. Of course a new sleeve must be used each time the assembly is taken apart and reassembled.

It is equally important that there be no radial movement of the pinion. In heavy duty units, the pinion is often "straddle mounted." That is, there is a bearing on each side of the pinion. Such a construction is shown in Fig. 46-43. The exploded view in Fig. 46-44 shows the actual parts in order of assembly.

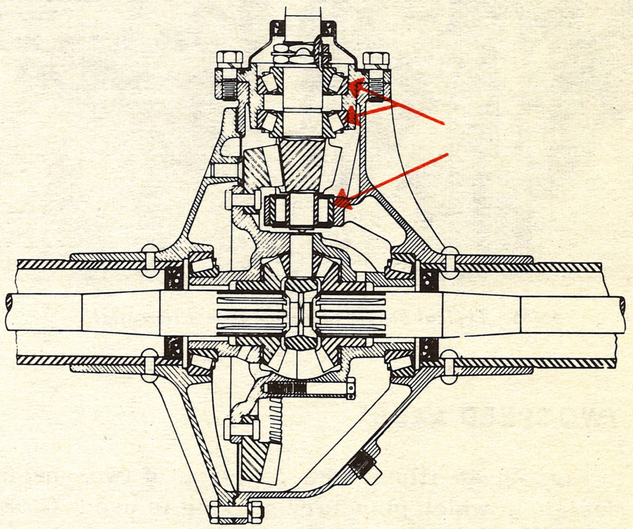


46-41. Pinion shaft and bearing assembly provided with a pre-load bushing.

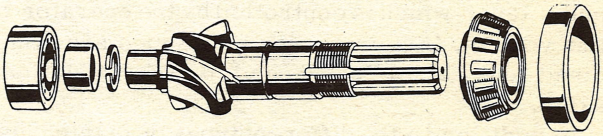


46-42. At left is a new pre-load sleeve before installation. At right a sleeve after use.

In addition to the types of differentials discussed in the foregoing there are variations such as "two-speed" and "double reduction." These differentials are ordinarily used in trucks, but two-speed units have been used in passenger cars. These units have been made in various arrangements and types. Figs. 46-45 and 46-46 illustrate two typical designs.



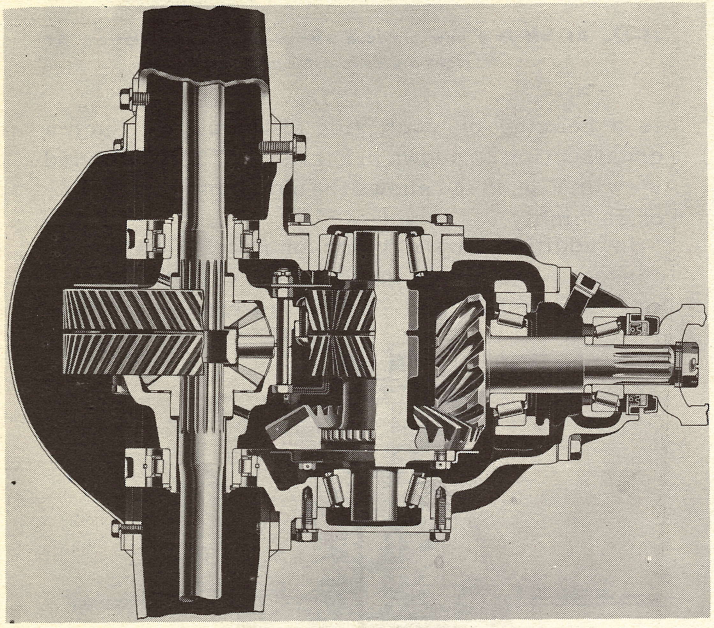
46-43. In this "straddle mounted" pinion, a pair of tapered roller bearings are used in front of the pinion gear and a roller bearing on the extended end of the pinion shaft.



46-44. Exploded view of "straddle mounted" pinion shaft.

DOUBLE REDUCTION AXLES

Fig. 46-45 is a double reduction type which uses a spiral bevel pinion meshed with a comparatively small ring gear for the primary reduction. The ring gear shaft is fitted with a herringbone gear which meshes with a like pair attached to the axle shafts to accomplish the secondary reduction.



46-45. *Typical double reduction gear differential.*

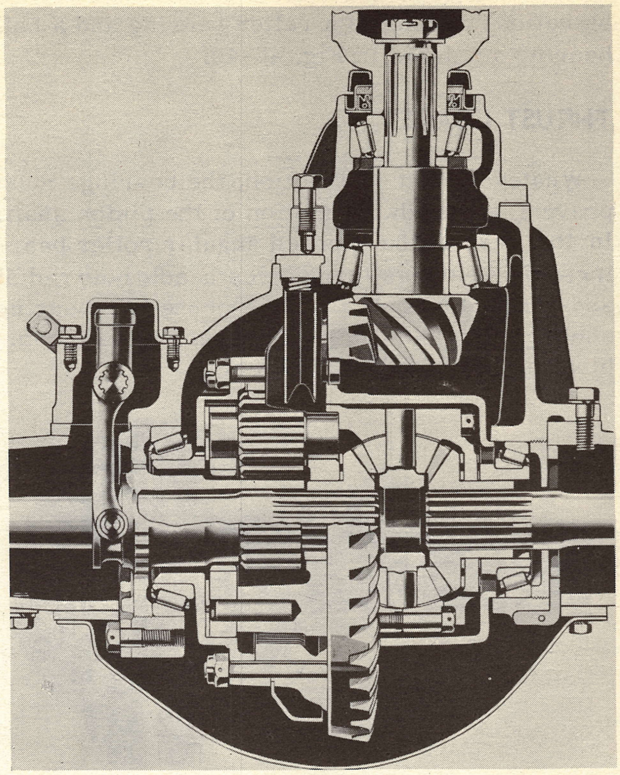
TWO SPEED AXLES

Fig. 46-46 illustrates one type of two-speed design in which planetary gearing is used. (For a full explanation of planetary gearing, see the transmission section of this text.) It will be noted that a means of connecting and disconnecting the planetary gearing is provided by a shifting collar and a lever which is controlled by the operator of the vehicle. In some cases both types are combined and called "two-speed, double reduction" axles.

In addition to the different types of gearing just described, axles used for driving vehicles are known as "full-floating," and "semi-floating." These designations have to do with the duties imposed on the axle shaft. In the full-floating type the axle shaft does not carry any of the car weight. Its sole duty is to propel the vehicle.

FULL-FLOATING AXLES

A typical full-floating axle construction is shown in Fig. 46-47. It will be noted that the axle housing is fitted with two roller bearings which carry the weight of the vehicle. The axle

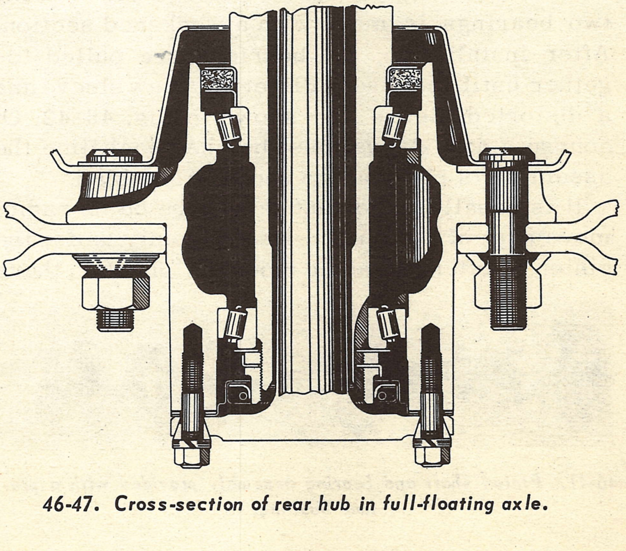


46-46. *Typical two-speed differential using planetary gears.*

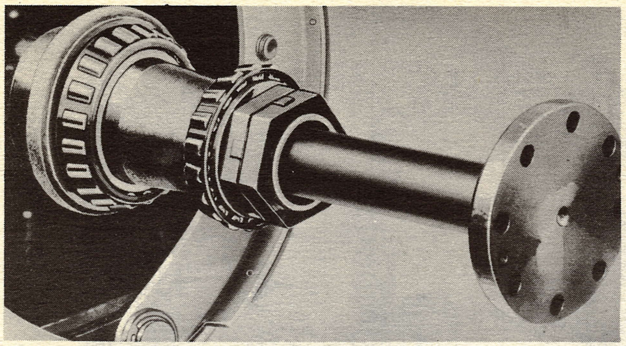
shaft is upset or flanged on the outer end and bolted to the hub. The axle can be removed without disturbing the wheel. The wheel removed and the axle shaft partially withdrawn is shown in Fig. 46-48. Fig. 46-48 also shows the bearing adjusting nuts.

SEMI-FLOATING AXLES

In the semi-floating type of axle, a bearing is placed between the axle shaft and axle housing as shown in Fig. 46-49. Thus the axle supports the weight of the vehicle in addition to being the



46-47. *Cross-section of rear hub in full-floating axle.*

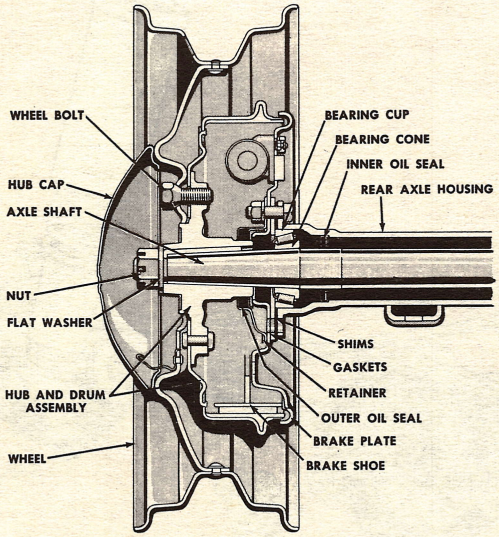


46-48. Bearing mounting and adjustment nuts of full-floating construction.

means of propulsion. It will be noted that the axle shaft is tapered at the outer end to fit into a tapered hub. It is also keyed in place and held by a nut on the threaded end of the axle shaft.

In order to remove the hub from the axle, it is usually necessary to use a wheel puller as a tight fit must be maintained between axle and hub.

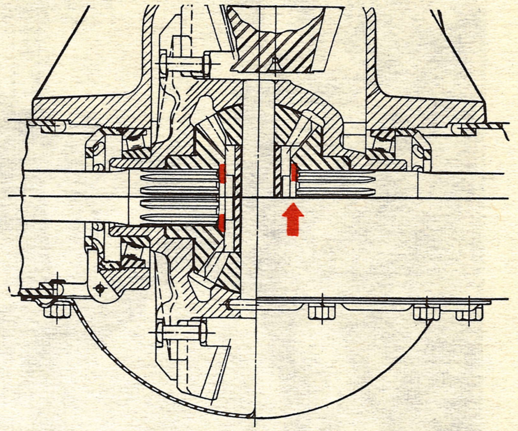
In order to remove the axle shaft of a semi-floating axle, it is often necessary to remove a "horse-shoe" washer or other retaining means



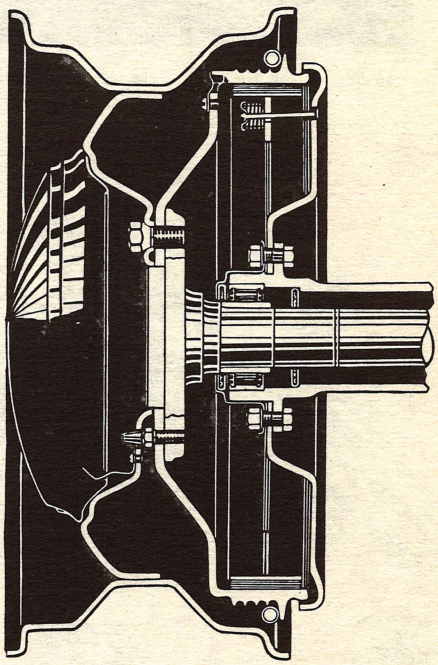
46-49. In the semi-floating axle, the axle shaft instead of the housing is the location of the wheel bearing.

on the end of the axle shaft within the differential case. This washer is shown in Fig. 46-50. It is also necessary to remove the bearing retainer within the hub as the wheel bearing inner race is a press-fit on the axle shaft. The bearing is adjusted by means of shims of varying thicknesses placed between the bearing cup and bearing retainer.

Another semi-floating design is shown in Fig. 46-51. In this case the hub is bolted to the flanged end of the axle shaft instead of being keyed. A straight instead of tapered roller bearing is also used on this axle shaft within the axle housing.



46-50. The location of the axle shaft retainer is indicated by the arrow.



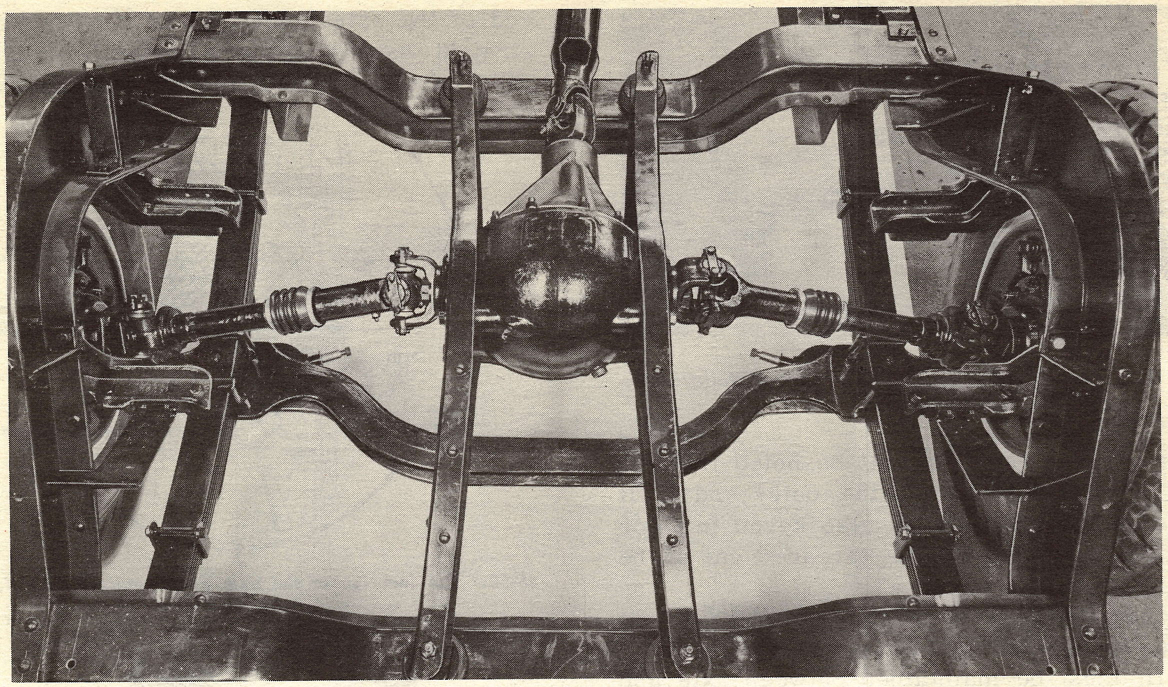
46-51. In this construction the end of the axle shaft is "upset" to form a flange which is bolted to the wheel hub.

DE DION SUSPENSION

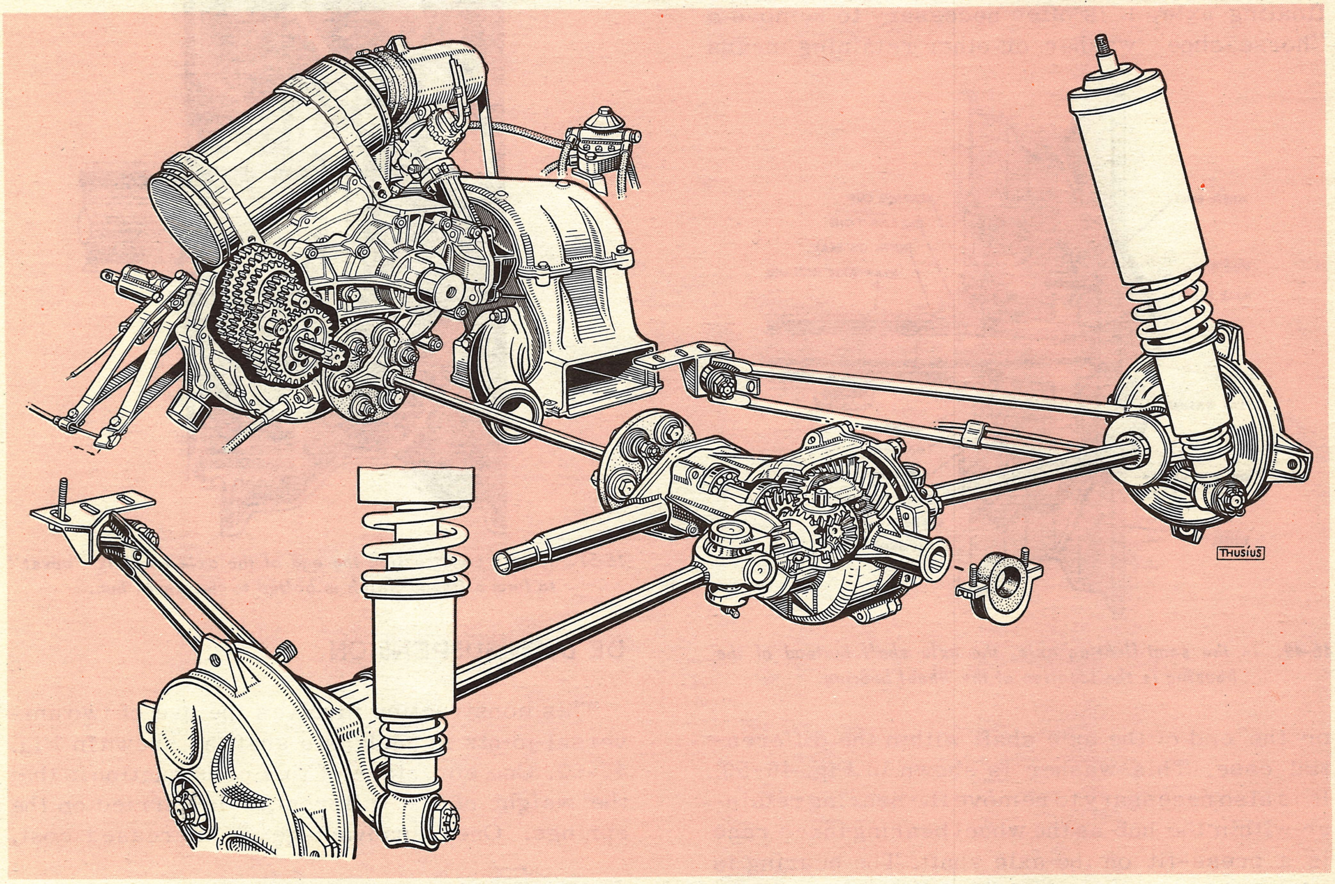
This construction involves the use of two universal joints in each axle shaft as shown in Fig. 46-52. One advantage of this construction is that the weight of the differential is carried on the springs. One disadvantage is increased cost.

INDEPENDENTLY SUSPENDED WHEELS

In the case of independently suspended rear wheels, the rear wheels may be on swing axles



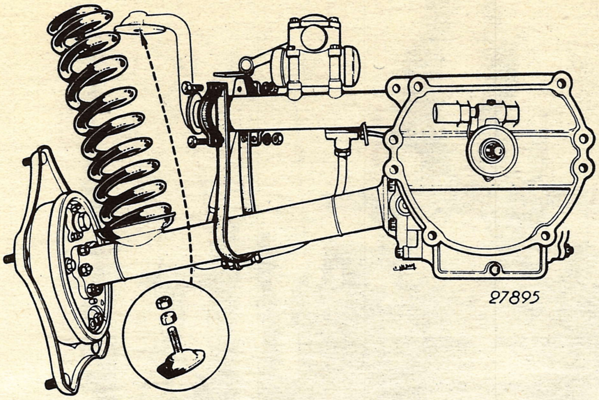
46-52. In the De Dion Type of construction, the differential is mounted on the frame but a solid axle and two swinging axle shafts are used.



46-53. Principal units of power and propulsion arrangement on German Janus small car.

as shown in Fig. 46-53 or on axle shafts using two universal joints as shown in Fig. 46-52.

Independent rear wheel suspension is popular on European built automobiles; notably the Volkswagen, Renault and several others. It is being used also on U.S.A. built automobiles.



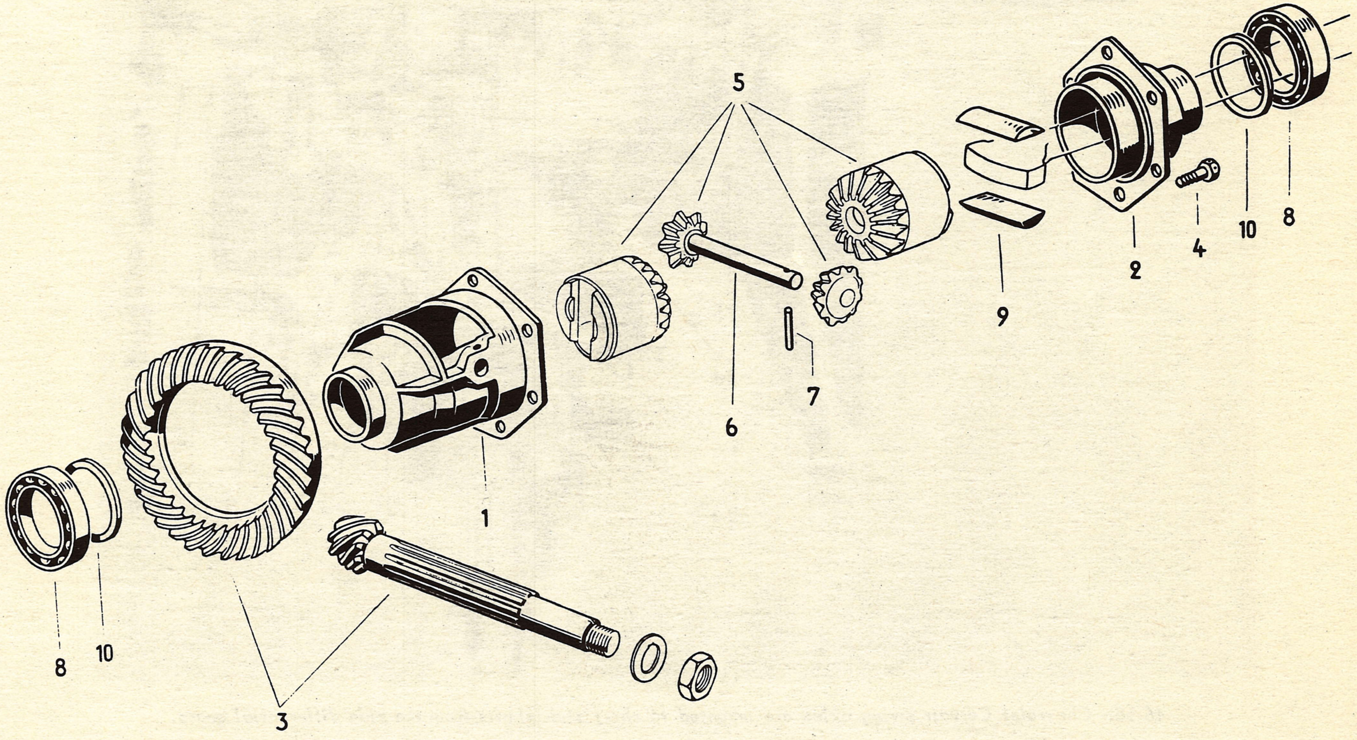
46-54. Independently suspended rear wheels as used on Renault. Differential is mounted on frame and swing axles are used for each rear wheel.

Examples are the Pontiac Tempest and Chevrolet Corvair as shown in Figs. 46-56, 46-57 and 46-58.

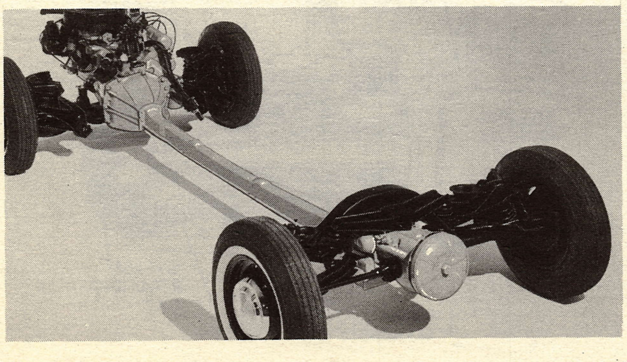
In the case of swing axles--unlike the De Dion type of suspension--the tread of the rear wheels varies as the wheels rise and fall. Also in some cases the rear wheels may be toed-in or toed-out slightly, depending upon the angles of the axle supporting means.

WHEEL BEARINGS

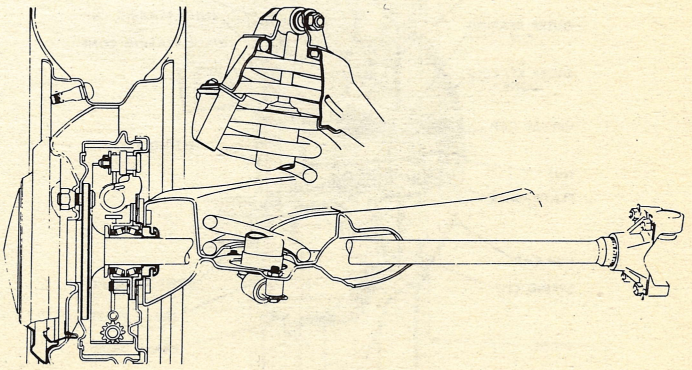
Each wheel hub, front and rear, ordinarily uses a pair of roller bearings as shown in Fig. 46-59, although Fig. 46-51 shows a single roller bearing. Some rear wheels and many front wheels use ball bearings, Fig. 46-60.



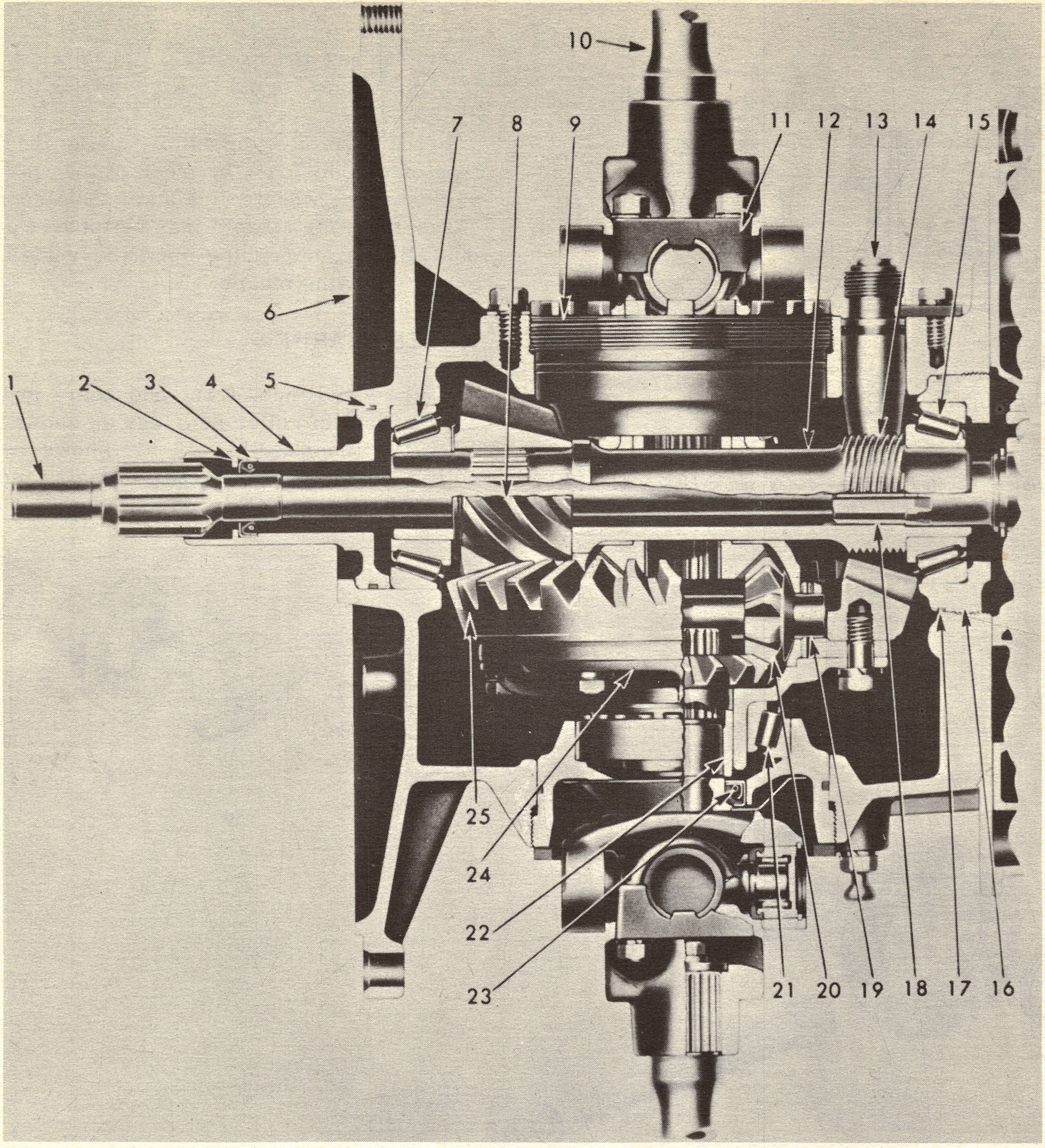
46-55. The Volkswagen swing axle shaft has a flattened inner end which operates between fulcrum plates within a spherical shaped housing on each side.



46-56. Pontiac Tempest rear wheels are independently suspended on swing type axles.



46-57. Details of Pontiac Tempest swing axle shaft.


10
7
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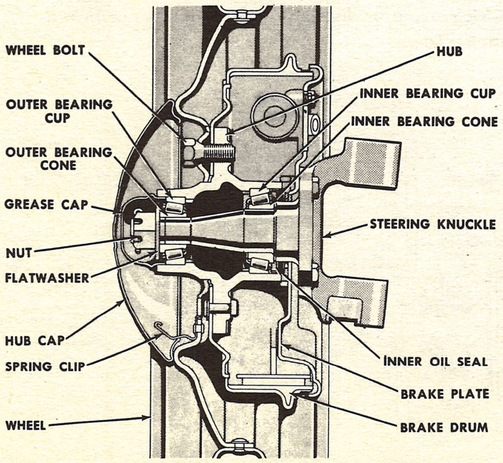
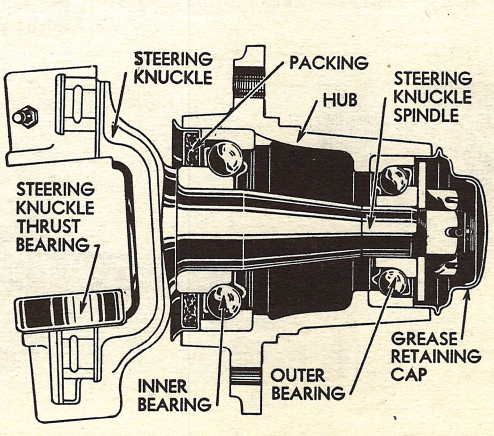
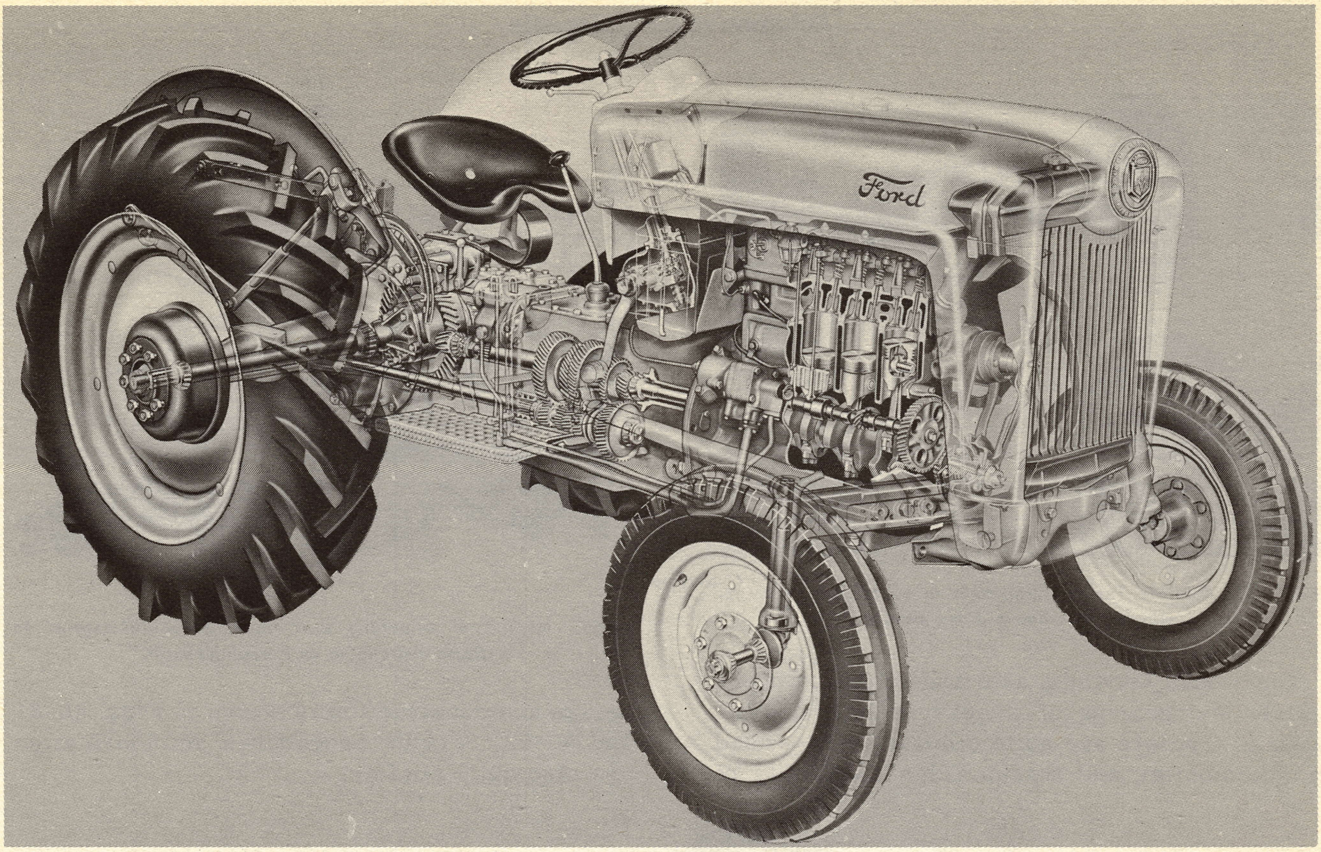
46-58. Chevrolet Corvair swing axles are mounted to short stub shafts from the side differential gears.


WHEEL BOLT
OUTER BEARING CUP
OUTER BEARING CONE
GREASE CAP
NUT
FLATWASHER
HUB CAP
SPRING CLIP
WHEEL
HUB
INNER BEARING CUP
INNER BEARING CONE
STEERING KNUCKLE
INNER OIL SEAL
BRAKE PLATE
BRAKE DRUM

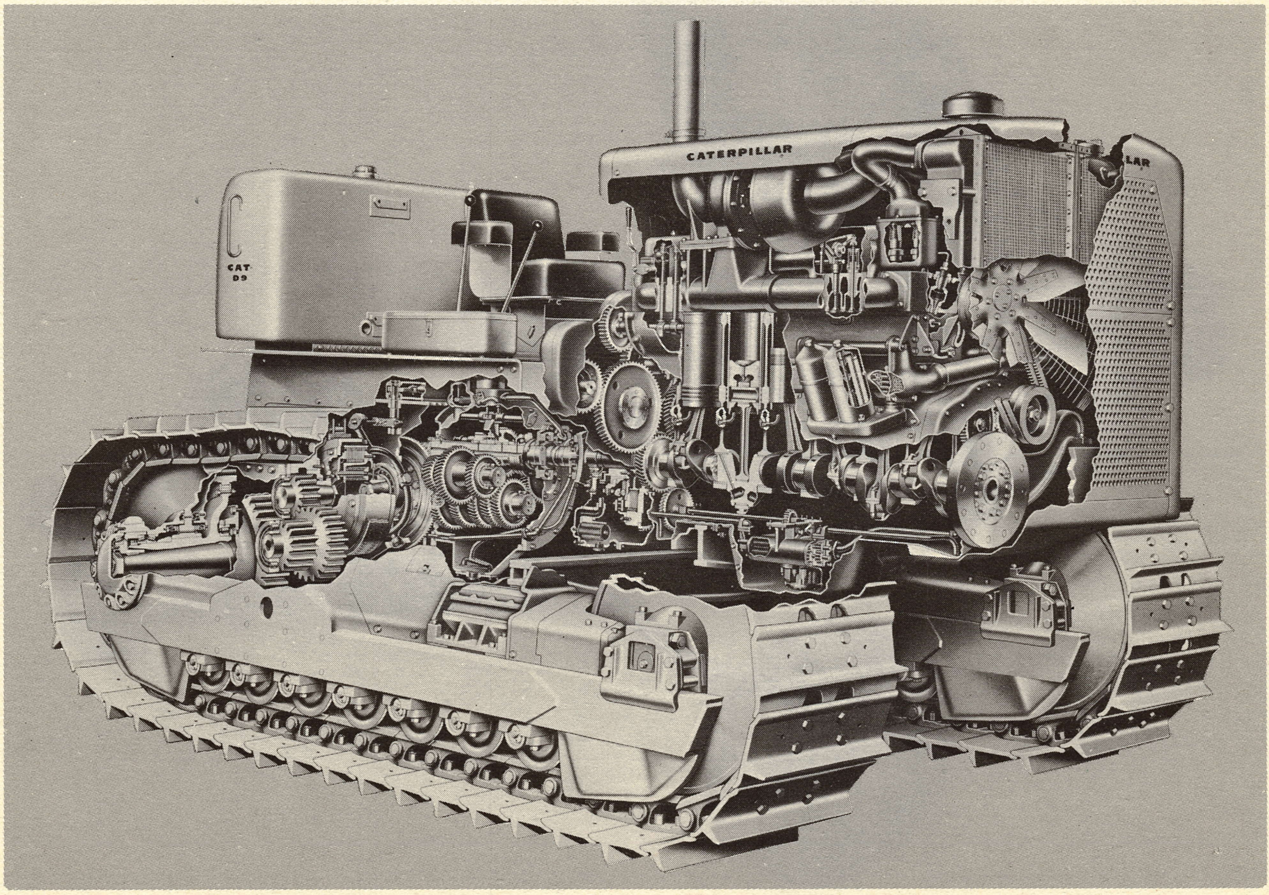
46-59. Typical roller bearing front wheel construction.


STEERING KNUCKLE
PACKING
HUB
STEERING KNUCKLE SPINDLE
STEERING KNUCKLE THRUST BEARING
INNER BEARING
OUTER BEARING
GREASE RETAINING CAP

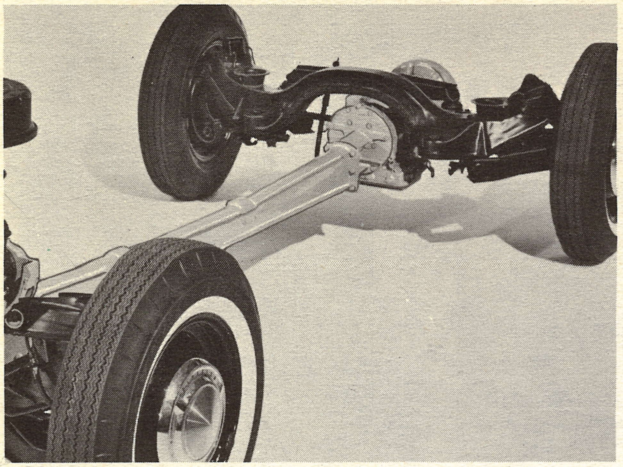
46-60. Typical ball bearing front wheel construction.



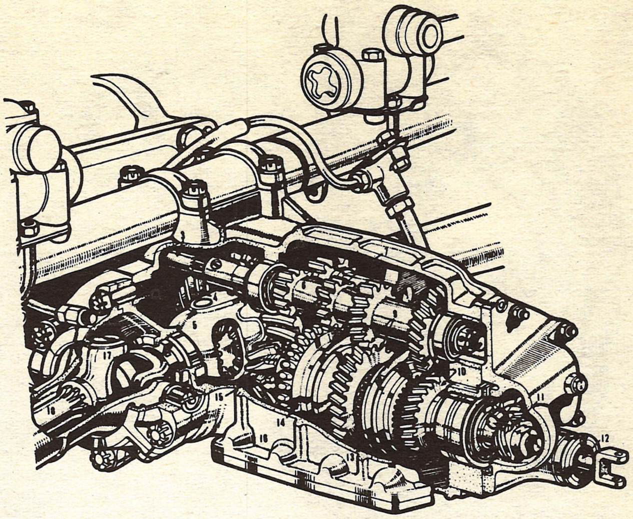
46-61. This phantom view of a modern tractor shows the similarity of drive line between tractors and automobiles.



46-62. This illustration of a Caterpillar Model D-9 shows the added complexity required in the drive line of a crawler-type tractor.

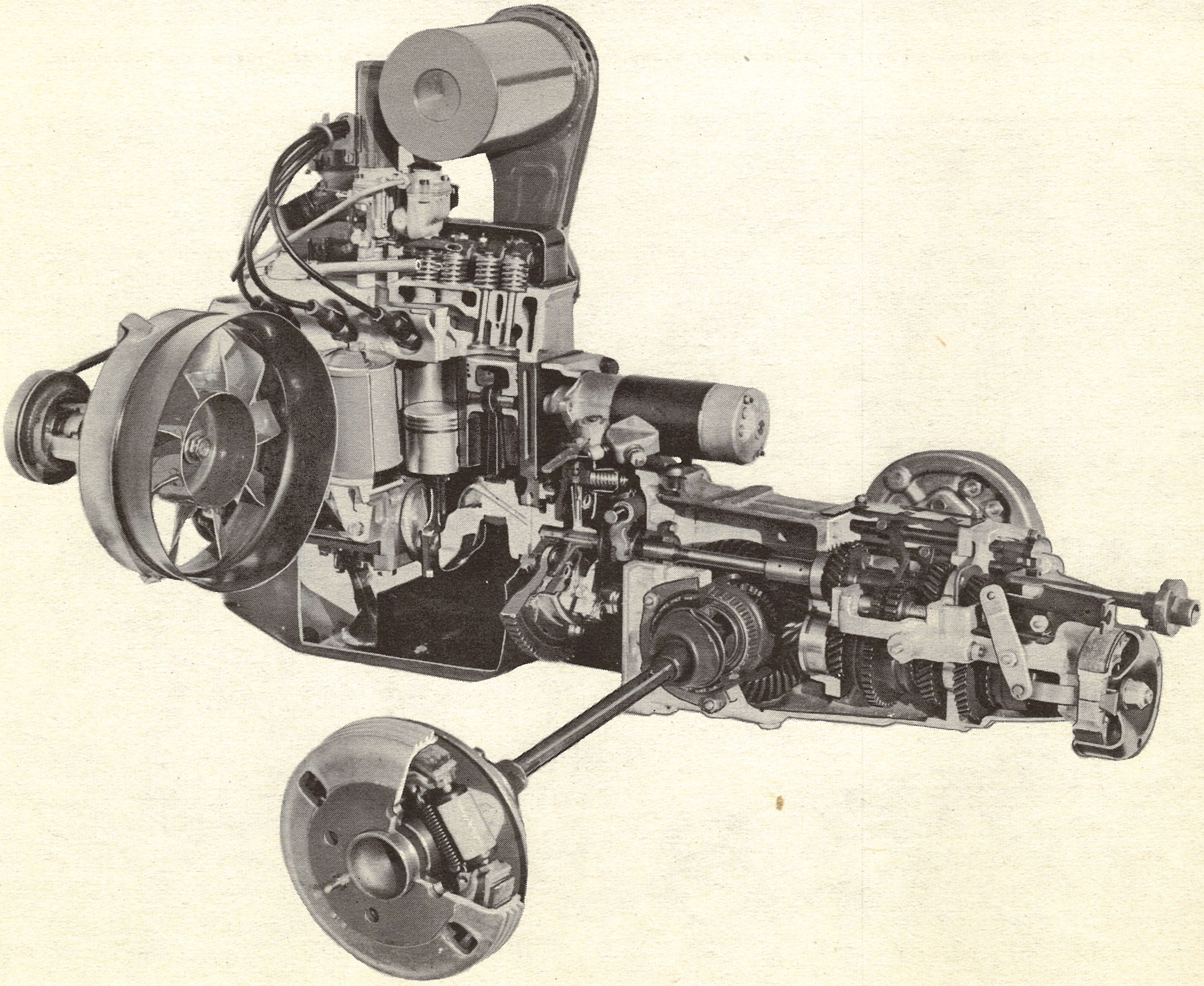


46-63. *The Pontiac Tempest transaxle is suspended under and attached to a heavy cross member.*

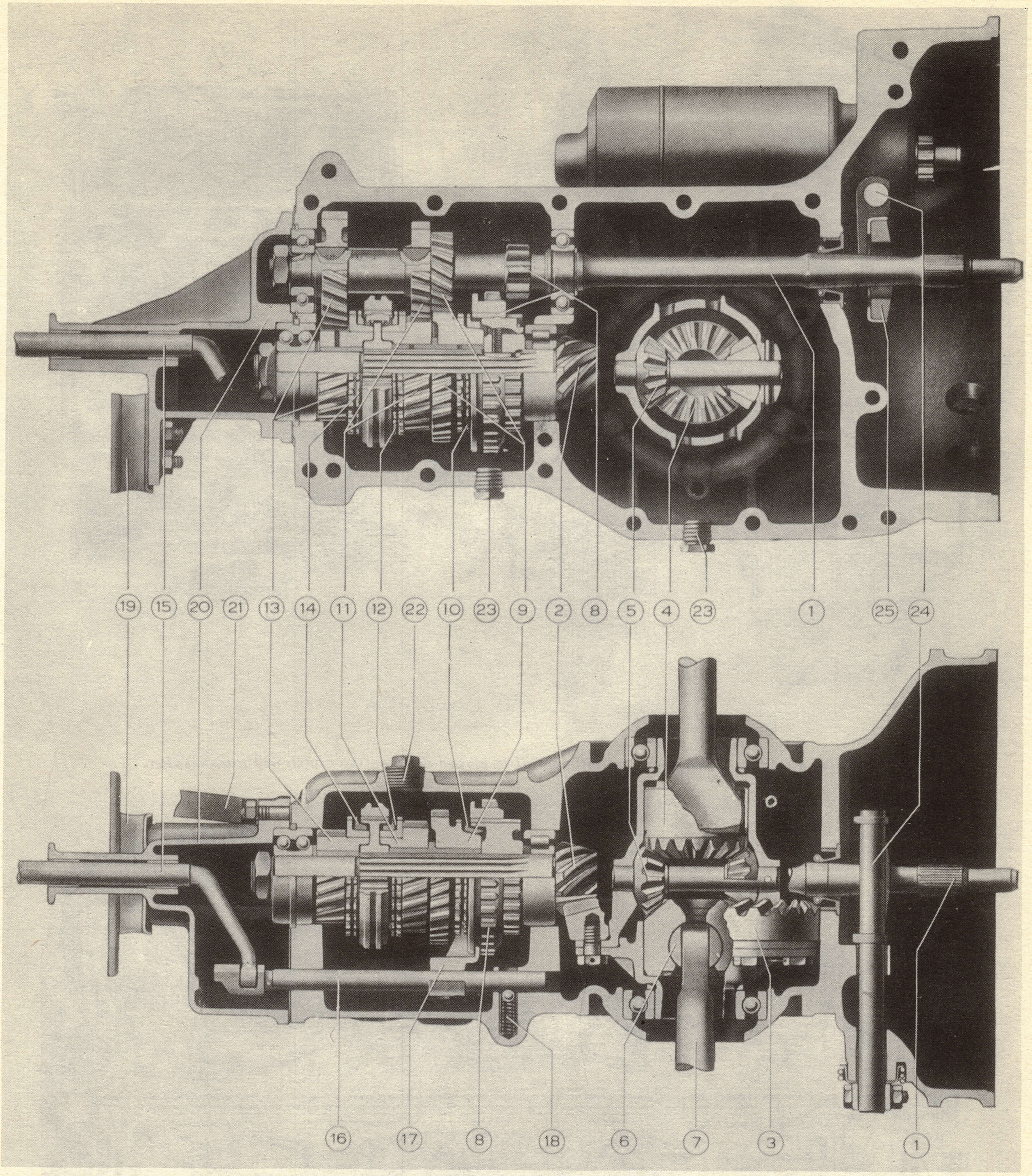


46-65. *Method of attaching unit transmission-differential to frame and engine on French Renault.*

The wheel bearings, axle assemblies, differentials and gearing of wheel type farm and industrial tractors are quite similar to those used in automobiles and trucks. This similarity of design and construction is shown in Figs. 46-61 and 46-62. Service procedures and lubrication are also quite similar.



46-64. *The Fiat 600 rear engine car has the transaxle bolted directly to the engine.*

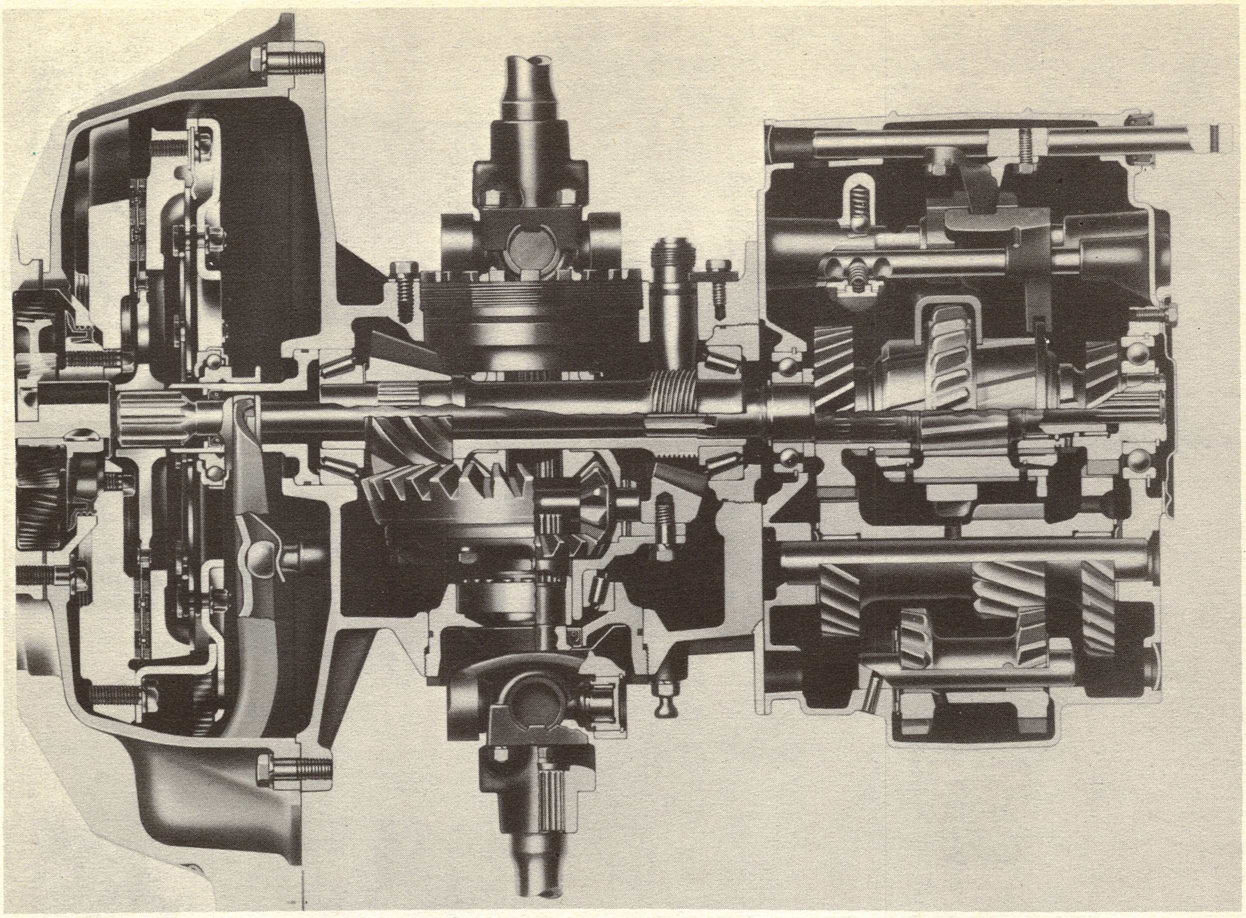


46-66. Synchromesh transmission as combined with differential on Volkswagen.

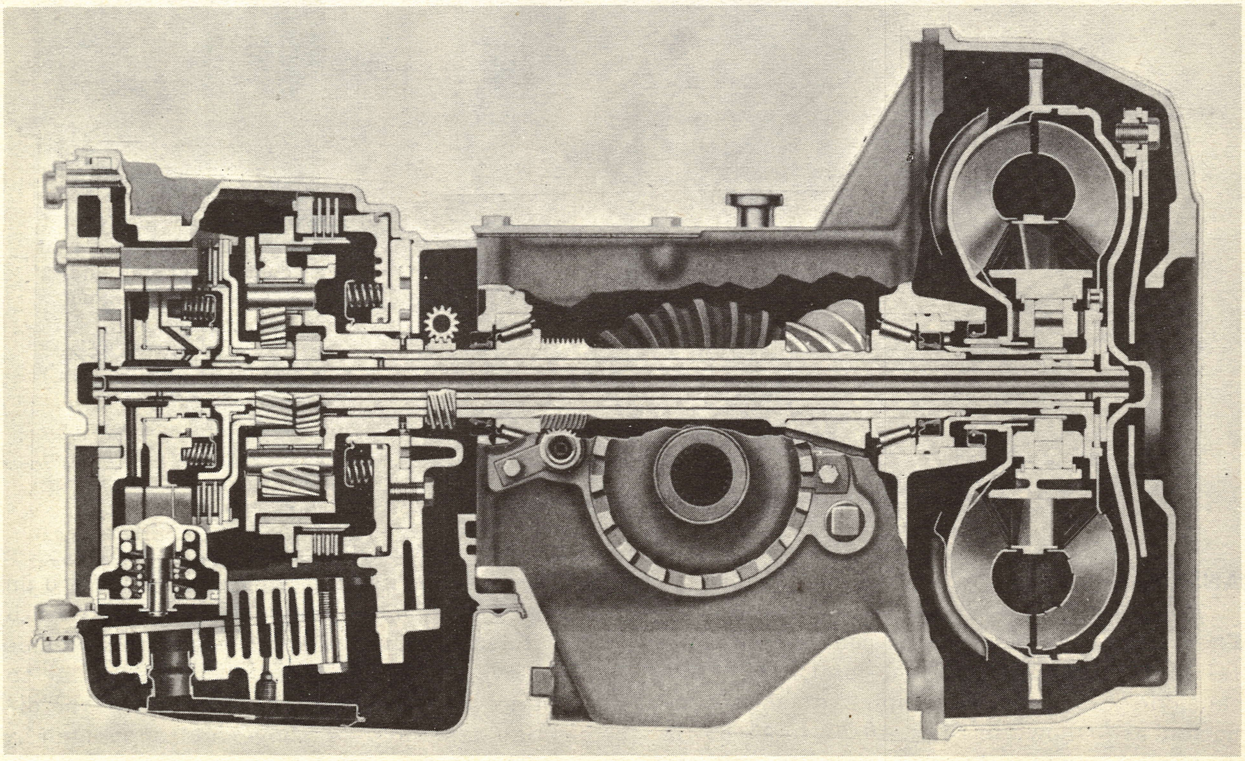
TRANSAXLES

Where the transmission and rear axle differential are combined in one unit, the term "Transaxle" is used. Examples of such construction are shown in Figs. 46-63 to 46-65. In rear engine cars, it is customary to bolt the transaxle directly to the engine.

Such construction has the advantage, among others, of providing an extremely rigid unit of engine and drive components. Much possibility of misalignment is avoided and compactness is achieved. By mounting the differential to the frame in this manner, the weight of the differential assembly is above and supported by the car springs and better riding qualities are obtained.



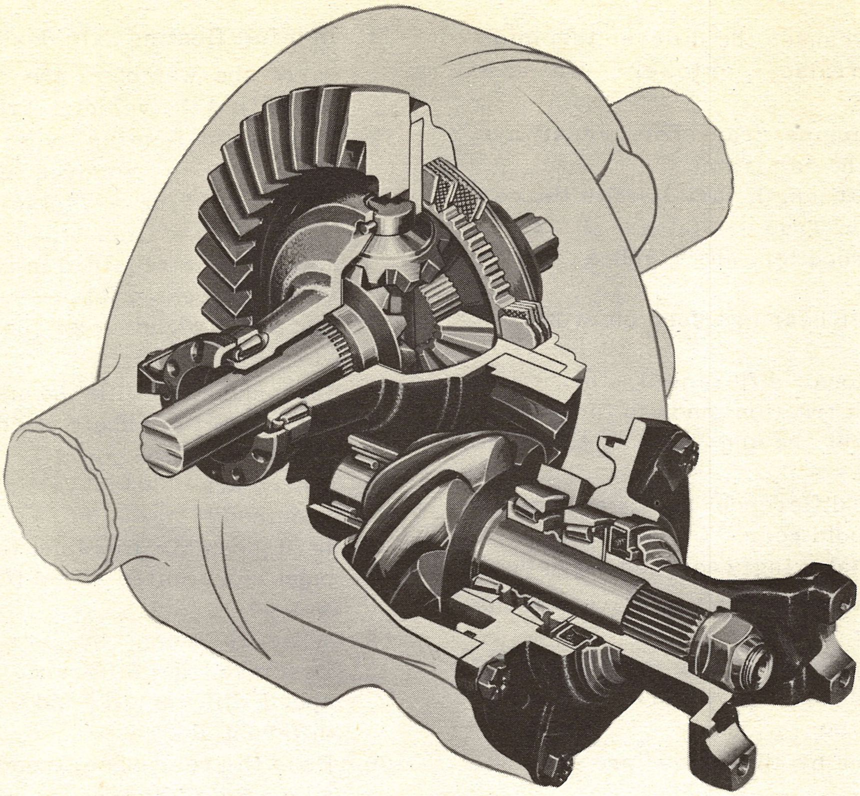
46-67. *In the Corvair transaxle, the differential is placed between the clutch and transmission.*



46-68. *When an automatic transmission is used on the Corvair, the arrangement is as shown here.*

QUIZ - DRIVE LINE, UNIVERSAL JOINTS

1. Engine torque causes the differential pinion shaft to tend to raise---or lower---when the car is backing.
2. Why is the engine crankshaft not always parallel with the car frame?
3. Propeller shaft length varies while the car is being driven. True---, false---.
4. Why must propeller shaft yokes be "in phase"?
5. Why are center bearings used on propeller shafts?
6. In a conventional differential, the wheel having the best traction tends to turn faster than the wheel having poorer traction. True---, false---
7. Describe the difference between a bevel gear and a hypoid gear.
8. The differential ring gear can be moved toward, and away from the drive pinion. True---, false---.
9. Can the differential pinion be raised or lowered vertically with regard to the ring gear? Yes---, no---.
10. What is meant by the term "pre-loading" a bearing?
11. In a full floating axle design, the axle shafts carry the weight of the car in addition to propelling the vehicle. True---, false---.
12. In a semi-floating type of axle, the axle shaft can be removed without disturbing the wheel. True---, false---.
13. With the De Dion type of construction, a solid axle is required in addition to the axle shafts. True---, false---.
14. Are rear wheels ever toed-in or toed-out? Yes---, no---.
15. In connection with the use of a transaxle, the propeller shaft need not be straight. True---, false---.
16. Where are constant velocity universal joints required?
17. Is it possible to adjust the amount of slippage in a limited slip differential? Yes---, No---.
18. What is meant by "straddle mounting"?
19. Describe the difference between a "two-speed differential" and a "double reduction differential".
20. Does the rear wheel tread ever vary on an automobile? Yes---, no---.



Ford Galaxie Equa-Lock differential.

DRIVE LINE SERVICE

PROPELLER SHAFT BALANCE

It may be readily understood that the constantly fluctuating speed of the propeller shaft as previously described and illustrated would have a tendency to cause vibration. Add to this any lack of rotating balance, and the result is serious vibration. Serious enough to shake the entire automobile and cause discomfort to the passengers.

For example, a weight of one ounce placed on the propeller shaft two inches from the center of rotation will exert a force of 50 lbs. at 3750 r.p.m. Also this force is exerted in opposite directions 62 1/2 times per second at 3750 r.p.m. Any such force will certainly cause vibration of serious magnitude.

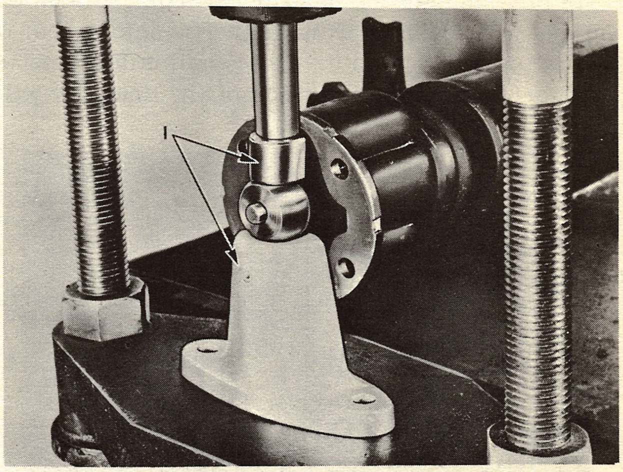
Even when the shaft is balanced as well as possible, it must be mounted so as to run true. The flanges to which the joints are bolted must be machined true and the spline machining must be accurate. For example, if the shaft is mounted .005 in. out of concentricity and weighs 25 lbs., it will develop the same 50 lbs. of force at the same speed as described in the preceding paragraph.

From this it may be seen why it is necessary to measure so carefully when replacing the cross pin in the type of joint shown in Fig. 47-1. This pin must be centered within .006 in. in the shaft end. It will also be obvious that the bolts, washers, nuts, etc. used to assemble the joints and flanges must all be of the same weight.

DRIVESHAFT REQUIREMENTS

Obviously therefore, propeller shafts using universal joints must be carefully and accurately manufactured, correctly assembled, straight, balanced, properly mounted in the automobile, and frequently checked. Even when all these things are done, they can get out of balance when in use. Journal cross bearings can wear. Splines can wear. Bolts and keys can become loose. The propeller shaft can become bent. Lubricant can become misplaced.

A special lubricant is required for universal joints of some types. This is for the reason that the high speed at which the joints rotate causes them to act as a centrifuge. Just as a cream separator takes the cream out of milk, the oil and soap of which the grease is made are separated. The heavier soap may fly outward and collect in a lump as shown in Fig. 47-2. This of course will unbalance the joint.

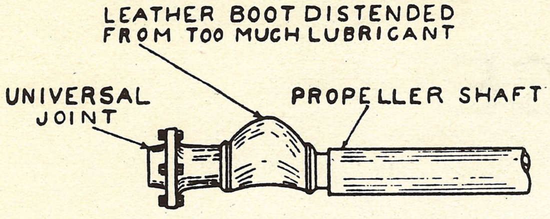


47-1. When installing the pin in the end of the propeller shaft, it must be centered carefully to avoid vibration of the driveshaft.

With the type of joint shown in Fig. 47-3, the lubricant is inserted in the plug hole in the center of the cross. The oil is then conducted to each journal through a passage drilled in the journal. If one or more of the passages become plugged up the oil may all collect in one journal bearing and cause unbalance.

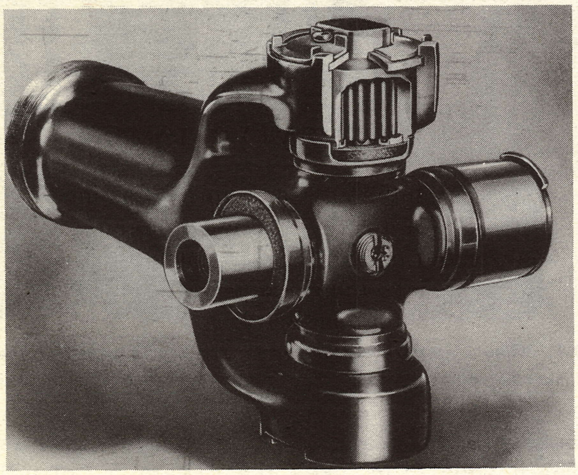
In another make of automobile which uses a hollow propeller shaft within a torque tube, the oil from the rear axle housing sometimes creeps along the pinion shaft into the hollow propeller shaft. It will often collect in one spot and create a very noticeable vibration. Such a condition requires the drilling of a small hole in the propeller shaft to wash the oil out with solvent.

Sometimes a propeller shaft is thrown out of balance by carelessly spraying undercoating on the outside of the propeller shaft when undercoating is applied. The propeller shaft should of course be shielded when undercoating is applied to the car.



47-2. The action of centrifugal force may cause the grease to collect at one spot inside the flexible boot and thus cause unbalance.

In other cases the hand brake drum is mounted on the propeller shaft near the transmission. If a wad of dust, mud or undercoating happens to land or collect on the inside of the drum, it will probably be held in place by the action of centrifugal force. The result is of course pronounced vibration.



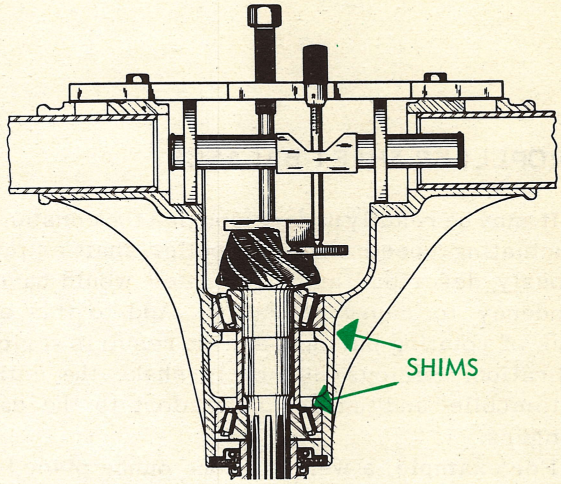
47-3. Lubricant flows to each journal of the cross through channels connecting with the plug hole in the center.

From the foregoing it may then be seen that universal joints should be kept clean, tight, and properly lubricated with the TYPE OF LUBRICANT specified by the car manufacturer.

PINION ADJUSTMENT

Sidewise adjustment of the ring gear toward and away from the pinion gear has been described. Examination of the many illustrations will also show that provision has been made for adjustment of the pinion shaft endwise.

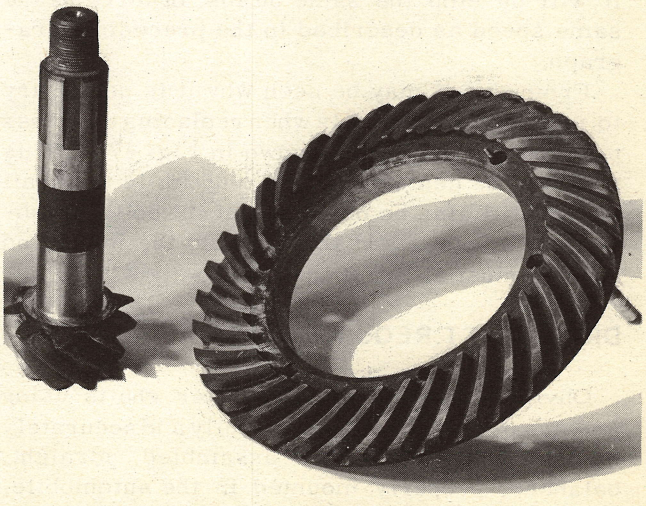
In cases where no screw type adjustment is provided, it is customary to use shims of various thicknesses behind the bearings as required to obtain proper mating of the gear teeth. The use of such shims is shown in Fig. 47-4 which also illustrates the use of a special gauge for setting the pinion in the correct position.



47-4. A special gauge is here used to locate the pinion at the desired position with regard to the ring gear.

MATED GEARS

In any case the adjustment must be made with great care in order to provide proper meshing of the gear teeth. In most cases the pinion and ring gear are mated to each other in manufacture and are furnished only in mated pairs. See Fig. 47-5. It is unwise to try to replace either one



47-5. Ring gear and pinion are mated to each other by a lapping process at the factory in order to obtain proper contact surface on the gear teeth.

and not the other. Excessive noise may be the result.

When a mated pinion and ring gear are installed and adjusted to the dimensions specified by the manufacturer they will usually have the proper contact between the teeth. In some cases, however, improper contact will be indicated by noise or overheating. In such a case, or where there is reason to suspect improper contact, it is desirable to check the surface.

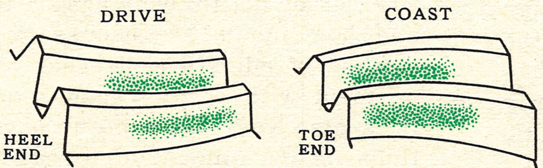
TOOTH CONTACT SURFACE

This is done by painting a thin mixture of oil and red lead on the sides of the ring gear teeth. The gears are then operated, both driving and coasting, for a short time and checked. The proper contact is shown in Fig. 47-6. Also shown are suggestions for correcting improper contact. The toe end of the gear tooth is the smaller of the two circles formed by the ends of the gear teeth.

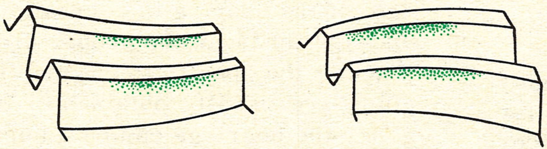
REPAIR AND ADJUSTMENT

Because of the tremendous power transmitted through the differential assembly, the pressures involved are exceptionally high. So high that considerable distortion of the heavy, and in most cases hardened, parts is bound to occur. Because of the high standards of quietness demanded, adjustments must be made to extremely close dimensions and distortion under stress held to a minimum.

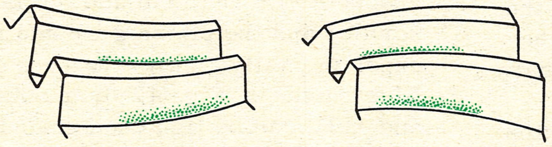
Thus of necessity all parts must be sturdy in construction and solidly mounted. For this reason, hardened anti-friction bearings are used. No other type of bearing could stand the speeds



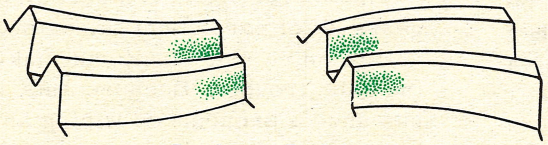
Ideal Ring Gear Tooth Contact Under Light Load



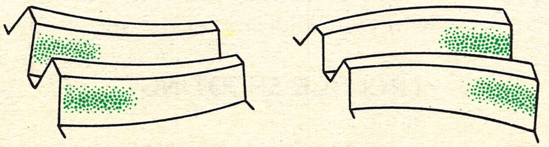
High Tooth Contact—To Correct Move Pinion Toward Gear



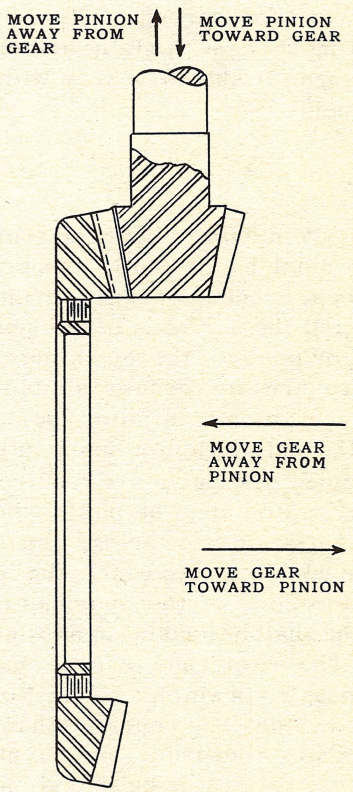
Low Tooth Contact—To Correct Move Pinion Away From Gear



Toe Contact—To Correct Move Gear Away From Pinion



Heel Contact—To Correct Move Gear Toward Pinion



47-6. The desired contact between ring gear and pinion teeth is not identical between the driving side and the coasting side as shown here.

and pressures and continue to maintain correct alignment of the gears. It should be realized that such high standards of manufacture involve equally high standards of careful work and adjustment when repairs are made.

When disassembling driving axle parts, it is essential to mark mating parts so that they can be correctly reassembled---for example, the two halves of the differential case, the pairs of bearing adjustments, etc. Furthermore, the gears and bearings are a press fit in many cases and hammers and drifts should be avoided. A suitable press or puller should be used to prevent chipping of hardened parts and distortion of other parts.

As an example, it is bad practice to chop the heads off the rivets when removing a ring gear from the differential case. Using a chisel is liable to distort the bolt holes or even the differential case. The proper procedure is to drill the head off the rivet and support the body solidly while the rivets are punched out. Before the gear and housing are reassembled, the flanges on the differential case to which the ring gear attaches should be checked for warpage. This is usually done by mounting the case in a lathe and checking with a dial gauge. It should be true within .002 to .003 of an inch.

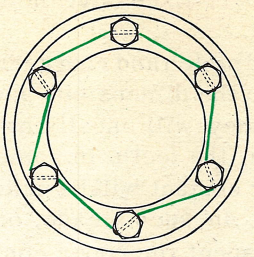
INSPECTION

After parts are disassembled and thoroughly cleaned, they must be carefully inspected for scuffed surfaces, cracks, warpage or any other visible defects. If the surfaces of the gear teeth are scratched or scuffed, the gears must be replaced. If there are any cracks visible in the differential case or any similar parts, they should be replaced. If the pinion bushings or shaft are worn or loose, new parts are required.

Particular attention must be paid to the pinion shaft and side differential bearings and the shaft or housings on which, and in which, the bearings seat. The inside cone of the bearings must be a tight fit on the shaft or housing upon which they are mounted. The outer race or cone must be a snug fit in the housing in which it seats. No looseness can be tolerated. The bearings themselves must not show any looseness or indications of wear. The races, rollers or balls and cups must be absolutely smooth and polished on the contact surfaces.

REASSEMBLY

When reassembling it is desirable to use new shims, spacers, washers, gaskets and oil seals. All capscrews must be locked in place either by locking strips or soft steel wire. See Fig. 47-7.



47-7. Proper method of wiring a ring of capscrews to prevent loosening.

The inside of the housing must be thoroughly cleaned of all grease and oil to make sure that no metal chips or abrasive material is left inside to be circulated by the lubricant.

FACTORY SPECIFICATIONS

The manufacturers' instructions concerning whether or not the bearings are to be pre-loaded, and how much, are necessary as well as the method of adjusting the gear contact by measurement with special gauges or micrometers. It is also very desirable to have the specifications on the amount of torque to be applied to all the bolts and nuts. When ball bearings are used it is important to make sure that the thrust side of the bearing is correctly placed to handle endwise thrust in the proper direction.

While the specifications mentioned in the foregoing are usually obtainable, in case of emergency the bearings can be adjusted so that there is no perceptible movement of the shaft and yet no bind in the bearing. The tooth contact can be checked with red lead and oil as previously described and the pinion gear and ring gear moved experimentally until the proper contact as illustrated in Fig. 47-6 is obtained. All bolts and nuts can be tightened gradually and equally to reasonable tightness if torque specifications are not available.

The correct gear contact adjustment on hypoid gears is of paramount importance because they will often be ruined without making any noise to indicate trouble. Because this type of gearing has such a pronounced wiping action between the gear teeth, they can overheat and gall the surface very quickly. A special kind of lubricant is required to prevent this galling even in normal service and correctly adjusted.

TROUBLE SHOOTING

In checking adjustment of gears by operating the vehicle or in diagnosing trouble as indicated by noise it is essential to use great care. This applies to passenger cars and to trucks whether driven by one or more axles. All too often a set of gears is condemned as faulty because of noise when the trouble is elsewhere. This is for the reason that noise has a tendency to appear in an automobile at some distance from where it originates.

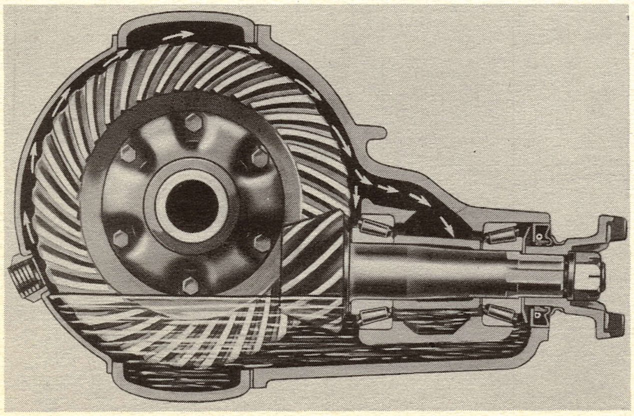
Only careful and thorough checking will determine whether the noise is in the differential, drive line, transmission or tires. This is particularly true of automobiles using torque tube drive. The torque tube will often carry the noise from the transmission to the differential or vice versa. Expert diagnosticians have been fooled many times by cupped tire treads or certain tread designs. Modern gears when properly installed and adjusted are exceptionally quiet unless improperly lubricated.

GEAR LUBRICATION

Proper lubrication is of utmost importance. Straight, bevel, and spur gears were successfully lubricated with a heavy mineral gear oil. When spiral bevel gears were adopted, it was found necessary to add some ingredients to the oil to enable it to withstand the high pressure sliding or wiping action of the gear teeth.

With the adoption of the hypoid type of gearing, the sliding action was greatly increased and the previously used straight gear oils and extreme pressure gear oils were found inadequate. Special hypoid lubricants were then developed and MUST be used with these gears. The vehicle manufacturer furnishes recommendations which must be followed.

As may be seen from Fig. 47-8, the ring gear acts as a circulating pump to distribute the lubricant over the gear teeth and to the bearings. As the oil is in constant circulation when the vehicle is in motion, any abrasive material or metal chips will be promptly carried to the working surfaces. If abrasive, undue wear of gear teeth and bearings will occur. If a metal chip goes through the gears the result will probably be broken gear teeth, parts sprung out of alignment, or both. Care must therefore be used to keep the oil clean before and during refilling.



47-8. Rotation of the ring gear distributes the lubricant to all gears and bearings in the differential.

TRANSAXLE LUBRICATION

It will be noted from previous illustrations that both helical gears and automatic transmissions are combined with the differential unit in transaxles.

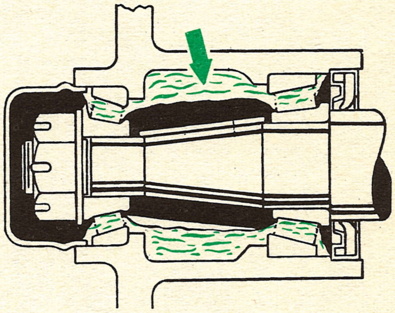
We have also seen that some types of gearing require an extreme pressure type of lubricant, while this lubricant is unsuited to other types of gears. Whether or not the transmission and differential are interconnected, there is always the possibility for lubricant to seep or leak from one unit to the other.

For these reasons, it is absolutely essential to follow the manufacturers instructions when adding to or replacing lubricant in a transaxle.

WHEEL BEARING LUBRICATION

While some wheel bearings are automatically lubricated by oil creeping along the axle shaft from the differential, others are sealed off and require separate lubrication. The manufacturer supplies lubrication charts which should be followed both as to type of lubricant and frequency of lubrication.

Many designs call for the use of a special wheel bearing grease. This is a short fiber grease with a high melting point. The high melting point is essential because the brake drums surrounding the wheel bearings often get hot. Really hot. Brake drum temperatures at times approach 700 degs. F. Of course all this heat is not applied to the wheel bearings, but a considerable amount is absorbed by the hubs. If the grease melts, it



47-9. The hub and hub cap should not be packed full of grease.

may find its way to the brake linings and ruin the brakes.

This special wheel bearing grease is almost invariably used for the front wheel bearings whether of the ball or roller bearing variety. In this connection, front wheel bearings are often overfilled. The hub should not be packed full of grease. The hub cap should not be stuffed full of grease. Fig. 47-9 shows a properly packed front wheel hub. The bearings are filled and a reserve placed in the hub. When the proper grease is used, this method provides adequate lubrication.

QUIZ - DRIVE LINE SERVICE

1. The cross pin in the end of the propeller shaft on some universal joints should be centered within; .006 in.---, .012 in.---, .06 in.---.
2. Why must a special grease be used in universal joints?
3. Give two reasons for propeller shafts getting out of balance when no mechanical change occurs in the parts.
4. How may the contact surface between pinion and ring gear be checked?
5. Differential parts should be marked for reassembly before they are disassembled. True---, false---.
6. Outside cup of anti-friction bearing must fit tightly in housing. True---, false---.
7. Why do hypoid types of gearing require a special type of lubricant?
8. Brake drum temperatures approach: 400 deg. F.---, 700 deg. F.---, 1,000 deg. F.---.
9. Wheel hubs should be packed full of grease. True---, false---.

AUTOMOBILE AIR CONDITIONING

Early attempts to provide a more comfortable temperature inside automobiles during hot weather involved the use of solid carbon dioxide (dry ice). This material remains at a temperature of -109 degs. F. and goes directly from the solid to the vapor state without becoming a liquid. Therefore it does not wet the surface it touches.

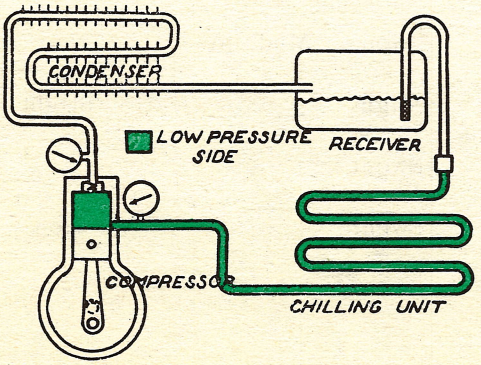
In hot climates a block of dry ice was placed in a container located in the car window or ventilator to absorb the interior heat. Frequent replenishment of the dry ice was required.

Modern automobile cooling systems are known as "air conditioners" and are quite similar to household refrigerators. As with other automotive apparatus, it is essential to understand the basic principles of operation in order to service them satisfactorily.

REFRIGERATION FUNDAMENTALS

All refrigerators are based on the thermal law that fluids absorb heat while changing from a liquid to a gas and give up heat in changing from a gas to a liquid. Changes from fluid to gas are often accomplished by means of heat. An example of this is boiling water to produce a gas or vapor (steam).

This same steam or vapor can be returned to liquid form---water---by cooling and condensation. An example of this is a glass of cold water in a warm room. The warm air collects on the outside of the water glass, becomes cooler and condenses into water.



48-1. In refrigerating unit liquid evaporates in chilling unit, absorbing heat.

The foregoing transformation of liquid into gas and vice versa occurs at atmospheric pressure. Higher pressures can also be used to reduce a gas to liquid form. The manufacture of liquid air and the reduction of petroleum gases to liquid form are examples of the use of pressure for this purpose.

APPLICATION OF REFRIGERATION

The method of using this thermal law to cool a space is shown in diagram form in Fig. 48-1. The liquid evaporates in the chilling units and absorbs heat. The heat-laden gas is then drawn into the compressor and discharged into the condenser where it cools and returns to liquid form. The amount of heat removed from the space to be cooled in the process is measurable.

HEAT MEASUREMENT

Any amount of heat is measured by a unit known as the British Thermal Unit (B.T.U.) and one B.T.U. is the amount of heat required to raise the temperature of a pound of water one degree Fahrenheit.

HEAT FLOW METHODS

Heat flows only from a warmer body to a cooler body. The movement may be any one or a combination of all three methods: conduction, convection, radiation. An example of conduction is an iron rod with one end in the fire; the heat travels along the rod to the other end. An example of convection is provided by warm air carrying heat from a furnace to a room by circulation. Radiation is the transfer of heat by heat rays such as the heat from the sun.

It may be seen, therefore, that the inside of an automobile body is subjected to conduction of some heat from the engine; convection of some heat from air circulation and radiation of heat from the sun. Of the three, however, radiation is the most important.

TEMPERATURE REDUCTION

The body may be insulated rather well from the engine heat. If the windows are closed the circulation of hot air may be avoided. If the car windows are fitted with special heat filtering glass, radiation from the sun will be reduced. Radiation of sun rays is further reduced by a visor over the windshield. It has also proved of value to paint the car, particularly the roof section in lighter colors. Sufficient insulation under the roof and inside the body panels will also help keep the passenger compartment cool and likewise reduce the work of the air conditioner.

HUMAN COMFORT

In dealing with human comfort we must consider things other than actual temperature:

A. Humidity control.
B. Air movement and circulation.
C. Air filtering, cleaning and purification.

The amount of humidity in the air affects the rate of evaporation of perspiration, so therefore we may feel uncomfortable even if the air is relatively cool when the air contains much moisture. Air circulation is also important because if cool, dry air is circulated past a warm body, radiation of heat from the body will increase.

Air filtering, cleaning and purification is also necessary to keep out dust, eliminate smoke and odors and add to comfort. For these reasons it is necessary to consider factors other than the actual temperature attained if an air conditioning or cooling system is to operate satisfactorily.

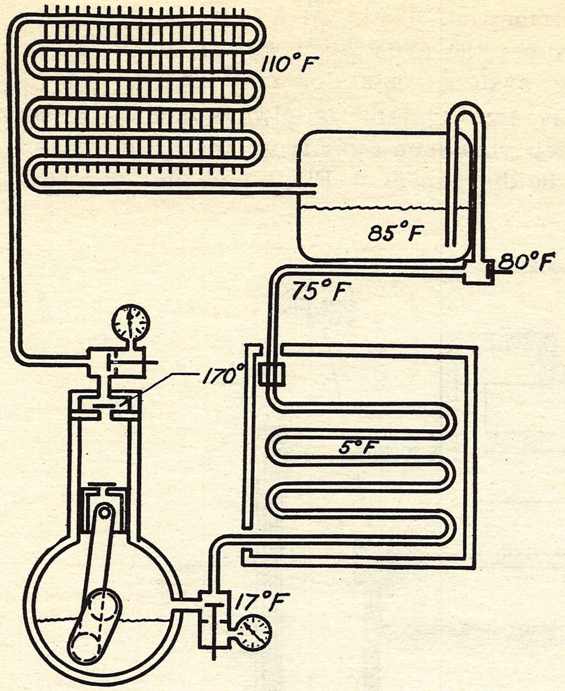
The temperatures attained in a typical refrigeration system are shown in Fig. 48-2 for purposes of comparison and are not intended to represent the actual temperatures in an automobile system.

REFRIGERANT TYPES

Further consideration of Fig. 48-2 will indicate that it is desirable to use a refrigerant that will change easily from a liquid to a gas and vice versa. Some materials are better than others for this purpose. The common refrigerants are:

NAME	CHEMICAL SYMBOL	TRADE NAME	ODOR	TOXITY	INFLAMMABILITY
Sulphur Dioxide	SO_2	--	Pungent	High	Non
Methyl Chloride	CH_3Cl	--	Sweet	Medium	Slight
Ammonia	NH_3	--	Pungent	High	Slight
Iso-Butane	$(CH_3) CH$	Freezol	Sweet	--	Yes
Ethyl Chloride	C_2H_5Cl	Alcohol	Etheral	Medium	Yes
Freon *	CCl_2F_2	F-12	Sweet	Low	Non
Carbon Dioxide	CO_2	--	Non	Medium	Non
Methyl Formate	C_2HyO_2	--	Slight	--	Slight
Methylene Chloride	CH_2Cl_2	Carrene	Sweet	--	--
F-114 **	$C_2Cl_2F_4$	--	Sweet	--	Non
F-21 ***	--	Thermon	Sweet	Low	--

* Dichlorodifluoromethane
** Dichlorotetrafluoroethane
*** Dichloromonofluoromethane



48-2. A refrigerating system showing the approximate temperatures of the refrigerant in the various parts of the system.

AUTOMOTIVE SYSTEMS

Automobile air conditioning systems are all similar and operate on the same general principle. They do differ considerably in detail, design and installation. The diagram, Fig. 48-3 shows the various units and methods of connecting them in a typical automotive installation.

COMPRESSOR

If there is to be continuous cooling the evaporator must receive a constant supply of liquid refrigerant and the evaporated refrigerant in the gaseous state must be removed from the evaporator. The refrigerant must also be pumped or circulated throughout the closed system.

This is accomplished by an engine driven compressor which may be of the reciprocating piston or rotary pump type. This compressor pumps the hot refrigerant under pressure to a condenser where the gas cools and returns to the liquid state.

CONDENSER

The condenser unit is similar to the engine cooling system radiator. The air flowing through the condenser core removes the heat and the refrigerant cools, condenses and returns to liquid form. The liquid then goes through a dehydrator before it reaches the thermostatic expansion valve.

DEHYDRATOR

All moisture must be kept out of the circulation as a trace of moisture could cause the expansion valve to stick. The dehydrator allows the refrigerant to pass through freely but traps any moisture. It is a small tank filled with a chemical such as silica gel which has an affinity for water.

EXPANSION VALVE

The liquid reaching the expansion valve is still under high pressure and liquids evaporate more rapidly under low pressure. The expansion valve reduces the pressure. As the compressor draws the refrigerant out of the evaporator, liquid tends to flow in and take its place. The spring loaded expansion valve restricts the flow until the pressure decreases in the evaporator side of the valve and the pressure builds up on the compressor side.

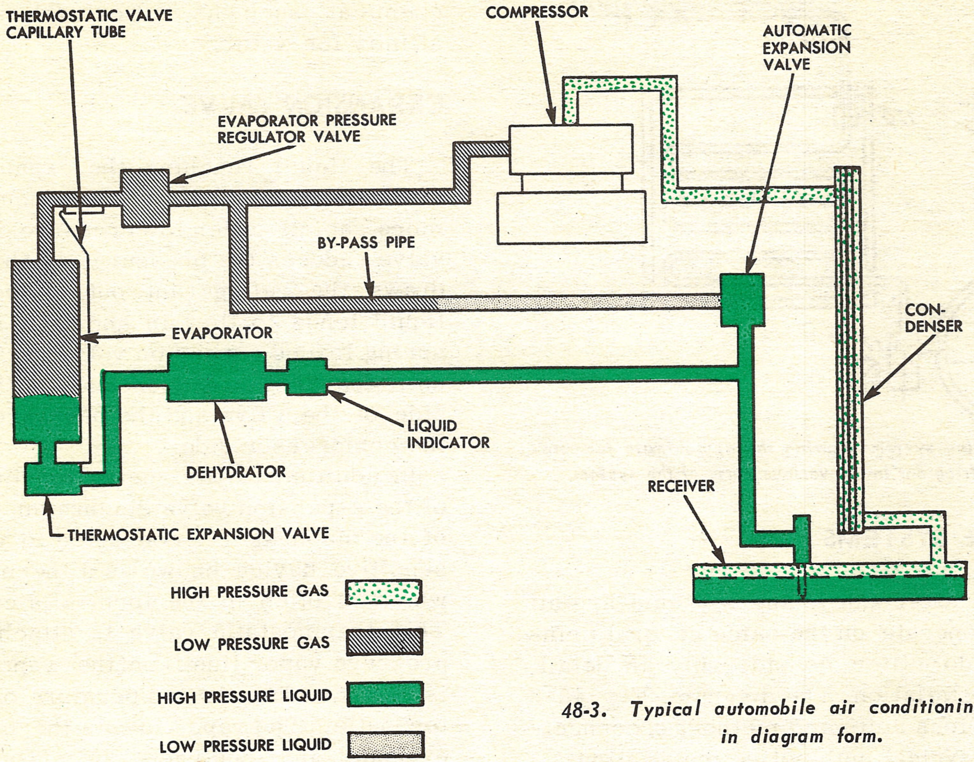
In addition to the spring loading on one side of the expansion valve diaphragm, the other side of the diaphragm is connected to a temperature sensitive device known as a thermostatic valve which is often in the form of a capillary tube. This thermostatic valve is attached to the low pressure vapor line from the evaporator and this is controlled by the temperature of the evaporator outlet. The vapor in this thermostatic valve expands and contracts in proportion to the temperature of the evaporator outlet. As the temperature rises the expansion acts on the expansion valve to increase the flow of refrigerant into the evaporator.

The increased flow of refrigerant causes faster cooling in the evaporator core. This reduces temperature at the evaporator outlet and of course reduces the flow of liquid again. The operation is continuous and automatic to thus meter the flow of fluid.

EVAPORATOR

Refrigerant in the liquid state enters the evaporator which is a radiator-like container. Here it is subjected to decreased pressure and exposed to increased area so it therefore will evaporate and absorb heat as previously explained. The heat laden refrigerant is then drawn into the compressor to complete the cycle.

It will be noted that another expansion valve is placed in the by-pass line. This is a balance or pressure regulation for the system and helps to prevent a freeze-up. It serves to by-pass vapor when the system is not cooling. On a cold day, the system may by-pass almost continuously. As the temperature rises, the by-pass will work less and less and perhaps in hot weather not by-pass at all.


THERMOSTATIC VALVE CAPILLARY TUBE
COMPRESSOR
AUTOMATIC EXPANSION VALVE
EVAPORATOR PRESSURE REGULATOR VALVE
BY-PASS PIPE
CON-DENSER
EVAPORATOR
LIQUID INDICATOR
DEHYDRATOR
RECEIVER
THERMOSTATIC EXPANSION VALVE
HIGH PRESSURE GAS
LOW PRESSURE GAS
HIGH PRESSURE LIQUID
LOW PRESSURE LIQUID

48-3. Typical automobile air conditioning circuit in diagram form.

In addition to the principal units just described there are various valves and fittings used in the different systems. Many of these valve types are described along with compressors in the Brake Section of this book. Pumps of the gear and rotor type are covered in the Transmission Section. Electric motors, solenoids, thermostats, etc. are covered in the Electrical Section and need not be dealt with here.

SAFETY REQUIREMENTS

While the materials used as refrigerants are generally considered safe to handle, certain precautions MUST be observed. The Society of Automotive Engineers in 1953 made safety recommendations calling for certain pressure and temperature sensitive valves to be used in an automobile installation.

At the same time they recommended that each unit be plainly marked as to the type of refrigerant used. Recommendations at that time also covered the following refrigerants: Carbon Dioxide, Carrene No. 1, 2; and Freon 11, 12, 21, 22, 113 and 114. Regardless of the type refrigerant used, ALWAYS wear goggles to protect the eyes when working on any part of the system containing refrigerant. Remember that the system is always under pressure. Keep your face away from any fitting when it is to be disconnected. Place a clean cloth over any valve or connection when it is opened. Be sure to close the shut-off valves provided before disconnecting the lines or fittings.

Because the system is tightly sealed, heat applied to any part will cause an immediate rise in pressure. To avoid a dangerous explosion, never weld, solder, use a blow torch, steam clean around or near any part of the air conditioning system.

Do not leave refrigerant drums exposed to direct sunlight or carry them in the passenger compartment of a car. When heat is required on the drum for charging the system never use water above 125 deg. F. and NEVER use a torch, stove or radiator as a source of heat.

GENERAL PRECAUTIONS

All connecting pipes should be kept free of dents and kinks as even a slight kink will greatly reduce the capacity of the entire system. All flares on tubing ends and on fittings must be free from scratches or burrs. When a joint is disconnected the pipe and fitting should both be capped immediately to prevent the entrance of air and moisture.

A gauge such as shown in Fig. 48-4 is an essential tool which is used for evacuating or charging the system as well as trouble-shooting. The low pressure gauge indicates pressure above the zero mark and vacuum below the zero mark. The other gauge shows pressures and is used on the high pressure side of the system.

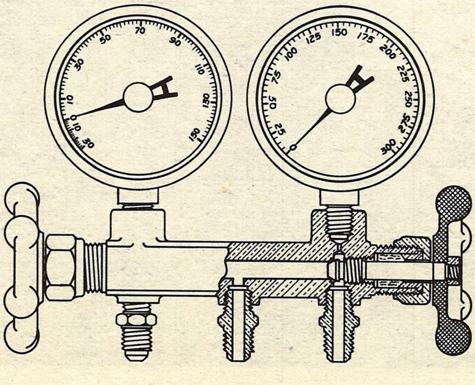
TEMPERATURE-PRESSURE RELATIONSHIP

Each kind of refrigerant has a different pressure-temperature relationship. Without a knowledge of this relationship it is impossible to make a proper diagnosis in trouble-shooting. The following table gives this relationship for Freon 12 which is the most popular refrigerant. This table does not apply to other materials.

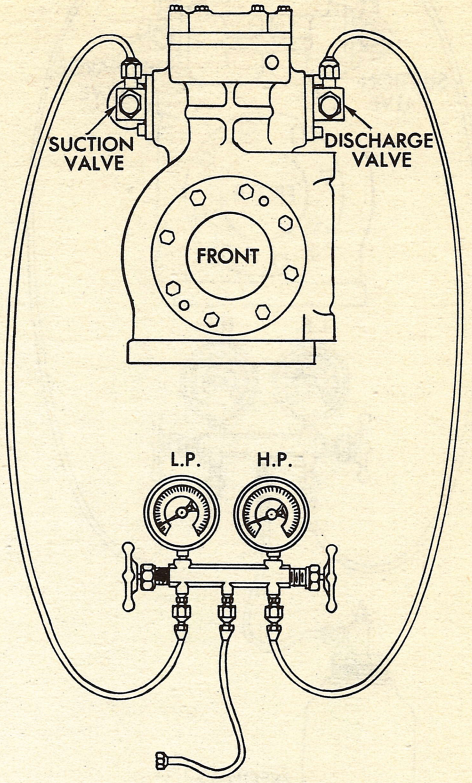
Temp. deg.F.	Pressure lbs. per sq. in.	Temp. deg.F.	Pressure lbs. per sq. in.
-8	5.4	60	58.0
-4	7.2	70	70.0
0	9.2	80	84.0
10	14.6	90	99.6
20	21.0	100	117.0
30	28.5	110	136.0
40	37.0	120	157.1
50	47.0	130	180.2

PUMPING DOWN

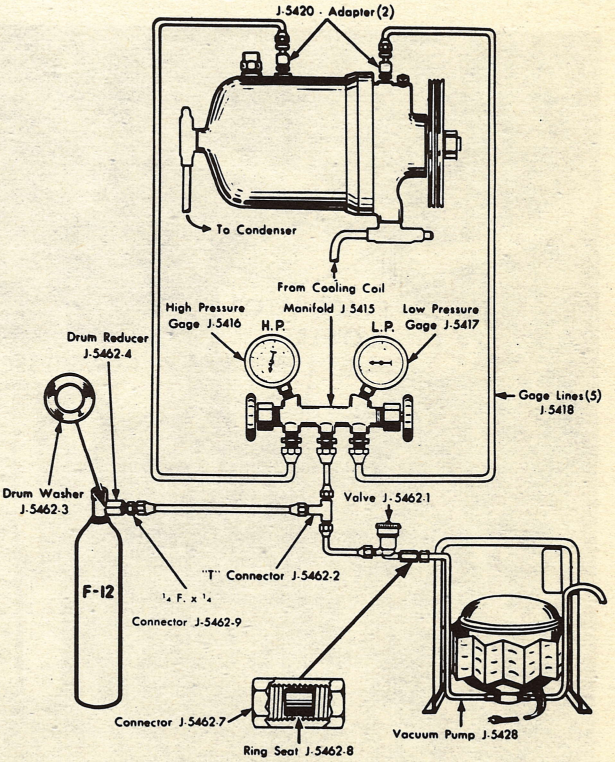
When it is necessary to remove or disconnect various units and it is desired to save as much refrigerant as possible the system can be "pumped down." This consists of pumping the refrigerant into the receiver and leaving it there while the work is done. In order to know what is going on in the system the gauges are connected as shown in Fig. 48-5. As the fittings, valves, units, etc. vary on different systems it is desirable to have specific instructions in each case. If these are not available study Fig. 48-3 and determine which valves should be


30
50
70
90
110
130
150
10
0
10
30
25
50
75
100
125
150
175
200
225
250
275
300

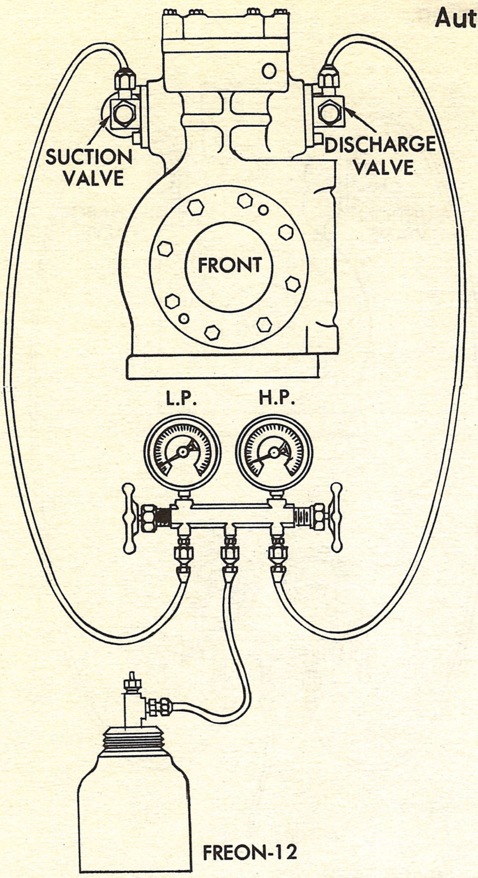
48-4. Air conditioning service gauge set.


SUCTION VALVE
DISCHARGE VALVE
FRONT
L.P.
H.P.

48-5. Method of connecting gauge set to compressor.


J-5420 - Adapter (2)
To Condenser
From Cooling Coil
High Pressure Gage J-5416
Manifold J 5415
Low Pressure Gage J-5417
H.P.
L.P.
Drum Reducer J-5462-4
Gage Lines (5) J-5418
Drum Washer J-5462-3
Valve J-5462-1
F-12
"T" Connector J-5462-2
¼ F. x ¼ Connector J-5462-9
Connector J-5462-7
Ring Seat J-5462-8
Vacuum Pump J-5428

48-6. One method of connecting vacuum pump to circulation system.



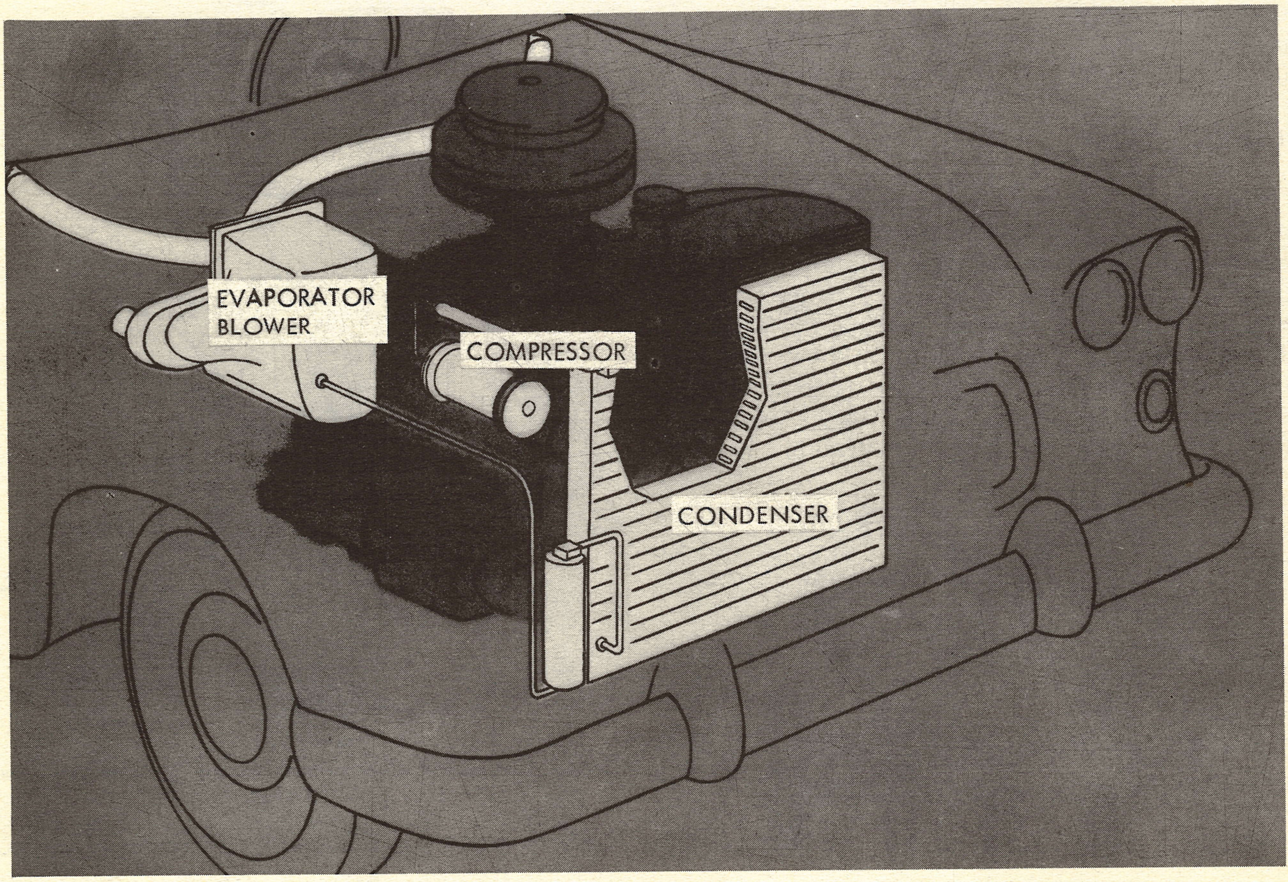
48-7. Connections for charging system.

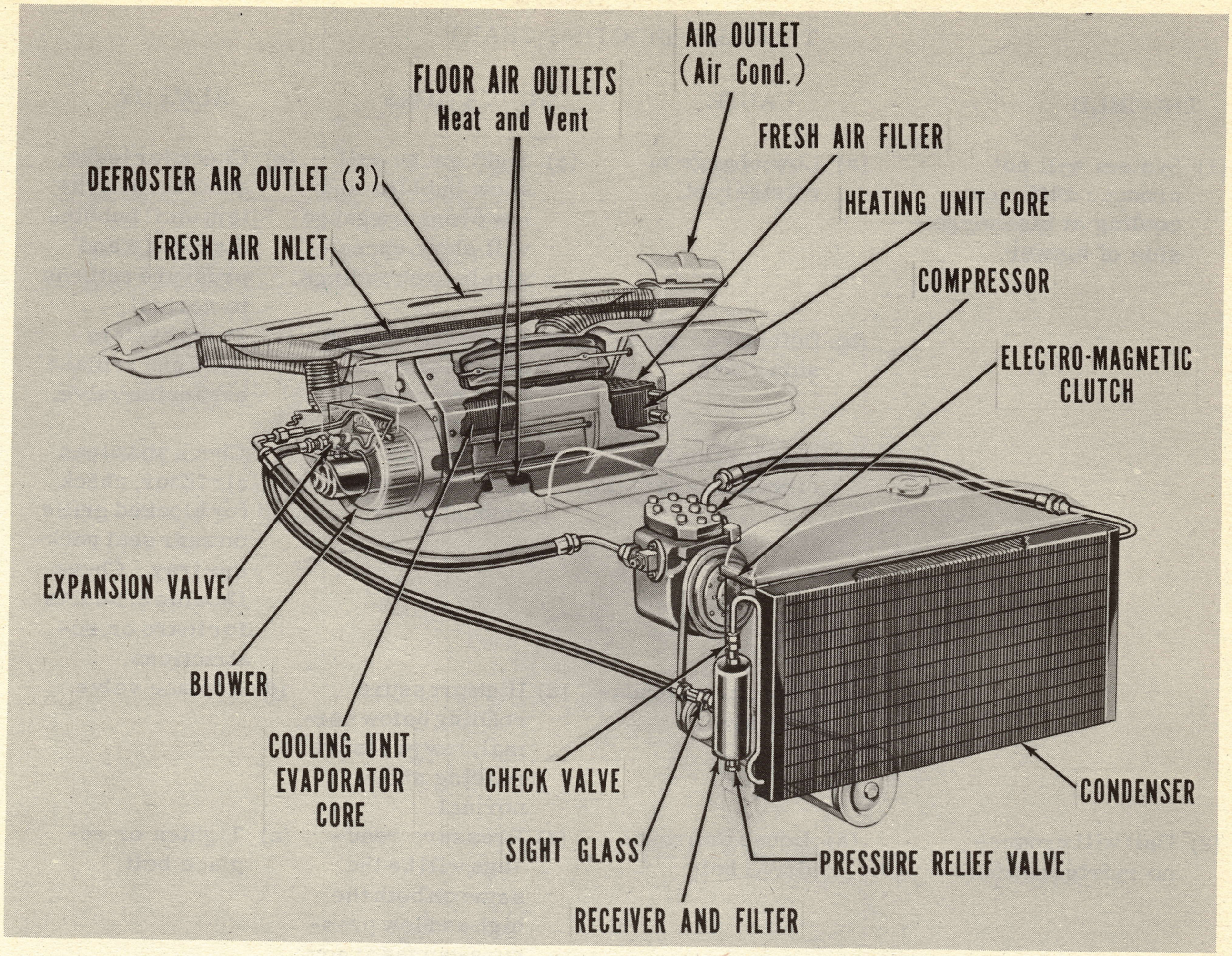
operated during the process.

When replacement must be made in the high pressure units such as the receiver it will be necessary to release the refrigerant. This may be done by opening one of the valves slightly to permit slow escape. If oil is noticed around the open valve the refrigerant is escaping too rapidly. Make sure that there are no open flames near the discharging refrigerant.

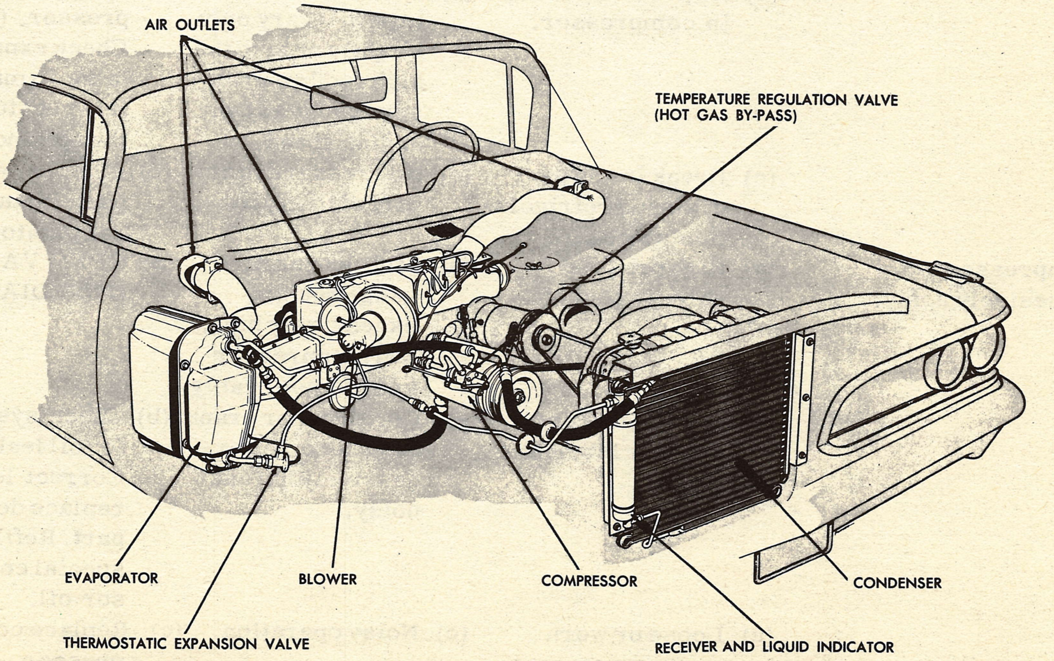
When the refrigeration system has been opened for service, some air will enter the pipes regardless of how quickly the openings are capped. In order to remove this air, and as much as possible of the moisture it contains, the system must be evacuated. A vacuum pump may be used for this purpose connected as shown in Fig. 48-6. NEVER put alcohol in the system in an attempt to absorb moisture.

After the system has been evacuated, or after a leak has been repaired or refrigerant lost for any reason, the system will need to be either partially or completely recharged. As the valves and arrangement differ so widely on the various systems, it is desirable to have specific instructions for the make and model. The method of introducing the refrigerant is shown in Fig. 48-7.




AIR OUTLET
(Air Cond.)
FLOOR AIR OUTLETS
Heat and Vent
FRESH AIR FILTER
DEFROSTER AIR OUTLET (3)
HEATING UNIT CORE
FRESH AIR INLET
COMPRESSOR
ELECTRO-MAGNETIC
CLUTCH
EXPANSION VALVE
BLOWER
COOLING UNIT
EVAPORATOR
CORE
CHECK VALVE
CONDENSER
SIGHT GLASS
PRESSURE RELIEF VALVE
RECEIVER AND FILTER

48-9. Basic units with additional details and accessories as installed.


AIR OUTLETS
TEMPERATURE REGULATION VALVE
(HOT GAS BY-PASS)
EVAPORATOR
BLOWER
COMPRESSOR
CONDENSER
THERMOSTATIC EXPANSION VALVE
RECEIVER AND LIQUID INDICATOR

48-10. This actual installation shows location and relation of air conditioning components to body and engine.

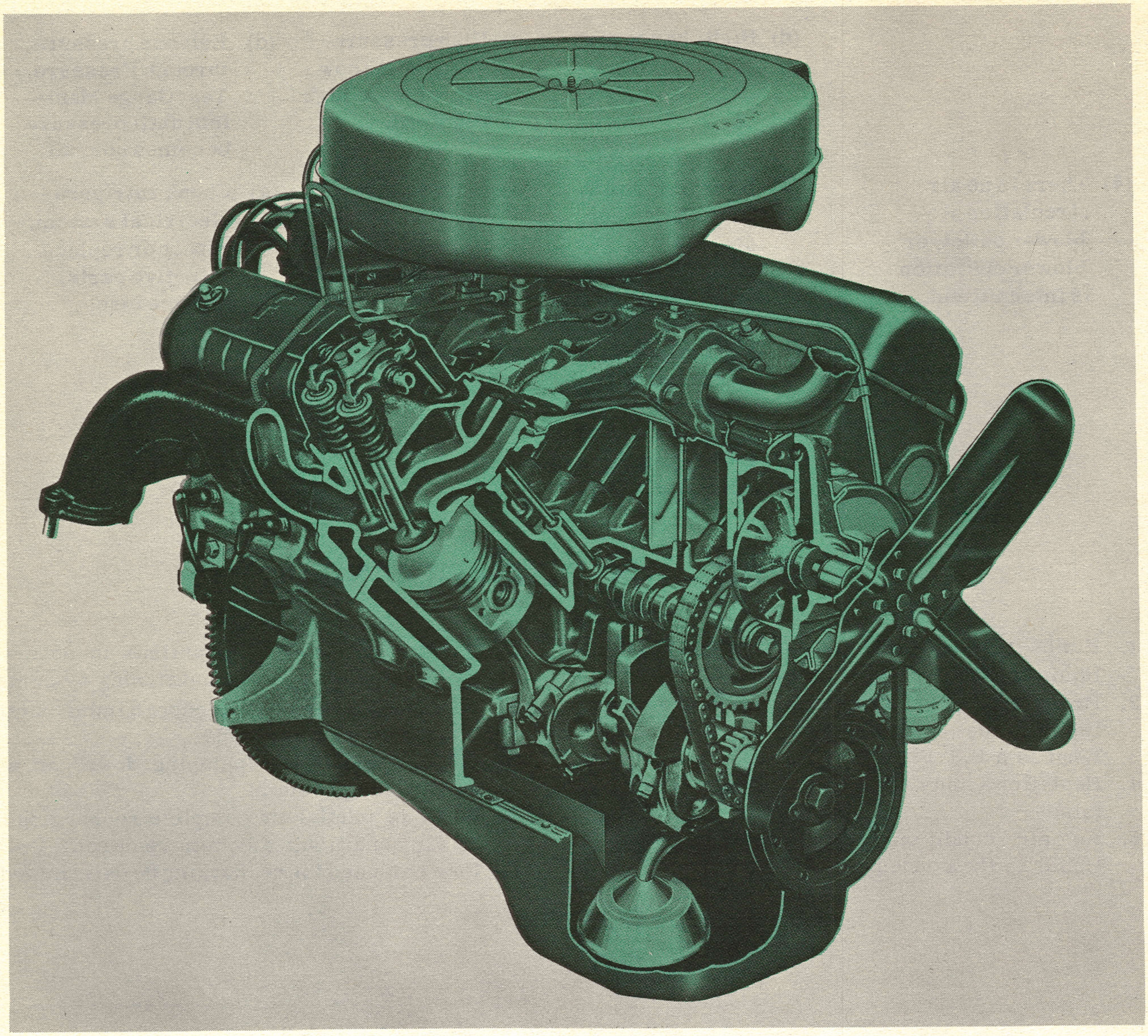
TROUBLE SHOOTING CHART

TROUBLE	CAUSE	INDICATIONS	REMEDY
(1) System will not produce sufficient cooling at discharge side of blower.	(a) Low charge of refrigerant.	(a) Sight gauge will show bubbles and low pressure gauge will show excessively low readings.	(a) Check for leaks, and charge system until bubbles disappear and pressure returns to normal.
	(b) Defective expansion valve.	(b) Excessively high and excessively low pressure readings.	(b) Pump system down and replace expansion valve.
	(c) Obstruction in air circulating system.	(c) Blowers will not circulate correct amount of air.	(c) Check and clean air filter, check for blocked grille on rear seat package tray. Check flexible air ducts for tears or restrictions.
	(d) Defective modulator valve.	(d) High pressure reading below normal; low pressure reading above normal.	(d) Replace valve.
(2) Unit will produce no refrigeration.	(a) Loose or broken drive belt.	(a) Pressure readings will be the same on both the high and low pressure gauges at any engine apeed.	(a) Tighten or replace belt.
	(b) Inoperative valves in compressor.	(b) Pressure readings will vary only slightly on both the high and low pressure gauges at any engine speed.	(b) Replace compressor. (Note: Check expansion valve to make sure it is not stuck in the open position.)
	(c) Break in any part of closed refrigeration system.	(c) No pressure in any part of the system.	(c) Replace defective part, install new dehydrator.
(3) Compressor is excessively noisy.	(a) High pressure valve is shut off.	(a) High pressure gauge reading excessively high, and compressor knocks noticeably.	(a) OPEN VALVE IMMEDIATELY.
	(b) Insufficient compressor lubricating oil.	(b) Compressor crank case becomes excessively hot and noisy.	(b) Check system for oil leaks. Correct leak or replace defective part. Refill with special compressor oil.
	(c) Loose or worn parts in compressor.	(c) Noisy operation.	(c) Replace compressor.

	(d) High charge of refrigerant.	(d) High pressure gauge will show excessively high readings.	(d) Release pressure through Pressure Test Gauge Manifold until pressure becomes normal.
(4) There is no air circulation at blower outlet, or blower operation is intermittent.	(a) Blower motors have shorted or open field or armature windings, electrical connections are loose or disconnected, electrical wiring is shorted or open or panel switches are inoperative. Burned out fuse.	(a) Blower motors operate intermittently or will not operate at all.	(a) Check refrigera-electrical system, repair or replace defective parts, replace fuse.

QUIZ - AIR CONDITIONING

1. Fluids give up heat while changing from a liquid to a gas. True---, false---.
2. Pressure can be used to reduce a gas to a liquid. True---, false---.
3. What is a B.T.U.?
4. Heat flows only to a cooler body. True---, false---.
5. An air conditioning compressor pumps liquid to the condenser. True---, false---.
6. Name five safety precautions to observe when working on air conditioning systems.
7. Why should any pipe be capped immediately after it is disconnected?
8. What is meant by "pumping down" an air conditioning system?
9. When is partial or complete recharging of an air conditioning system required?
10. How can need for recharging be determined?



Section view - Mercury Monterey engine, 292 cu. in. V-8.

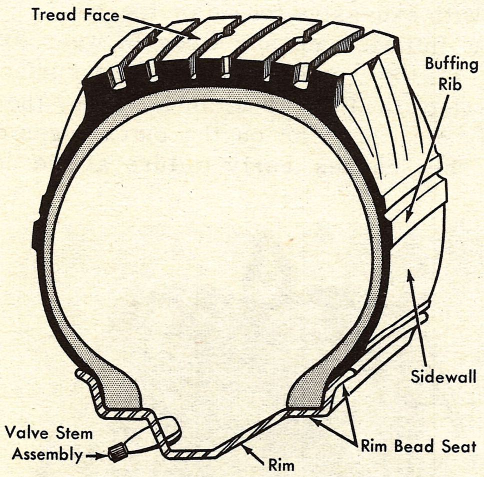
TIRES AND TIRE SERVICE

Without the pneumatic tire, the modern automobile would be an impossibility. In addition to comfort, the tire also contributes to speed and safety. It is designed to provide traction for the vehicle, and at the same time, absorb irregularities of the road surface so that they are not transmitted to the vehicle.

TIRES TYPES

At the present time there are two main types of tires; the tubeless and those requiring inner tubes.

The tubeless tire is so designed that the air is sealed within the rim and the tire casing, Fig. 49-1. When an inner tube is used, the air is contained within the tube, while the outer casing serves only to protect the tube and absorb the road shocks.



49-1. Cross section of modern tubeless tire.

Tubeless tires are now used on passenger cars and trucks of all sizes, while tires requiring tubes are found only on older vehicles.

Tires may also be classified as to the type of tread. Different types of treads are available for different types of service. These treads include:

1. Highway tread for use on improved highways.
2. Off the road tread for off the road work such as farm tractors, etc.
3. Snow tread for use on snow and ice.
4. Two-way tread for use on and off the highway.
5. Super Traction tread for use on vehicles working on soft earth.

In addition there are special treads for vehicles operating primarily on sandy terrain, and a rock tread for mine and quarry work. There are also special treads for racing.

Passenger cars are fitted with tires having a highway type of tread, or a two-way tread.

TIRE MATERIALS

A cross section of a typical tire casing is shown in Fig. 49-1. Tread material consists of varying proportions of natural and artificial rubber, and cords which are usually of rayon or nylon. Other cord materials such as aluminum and steel are also used in some tires. Cotton is no longer used for the cords in tires. Bead wires when used are of steel.

There is a controversy among authorities regarding the relative merits of rayon and nylon for tire cords.

Wire cord tires are noted for their strength and are used primarily for off the road use. On buses they are used primarily on the front wheels because of greater safety.

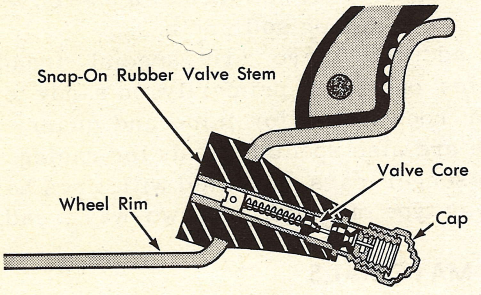
TIRE INFLATION

When inflating a pneumatic tire, consideration must be given to its temperature, as the pressure in a warm tire is higher than in a cold tire. Pressures as specified by the car and tire manufacturer apply to tires that have not been driven for at least three hours, or driven less than a mile at moderate speed. Also if air temperatures are below freezing, tires should be inflated two pounds higher. If the car has been driven three or more miles at speeds below 40 miles per hour, the pressure in the tires should read two pounds higher than normal. Pressure four pounds higher than normal is considered correct on tires which have been driven at least three miles at speeds in excess of 40 m.p.h.

Manufacturers emphasize that it is impossible to inflate tires correctly when they are hot. Pressures normally increase as tires get warm as the result of road friction and friction within the tire due to flexing. Tires should not be deflated to offset this increase in pressure.

TIRE VALVES

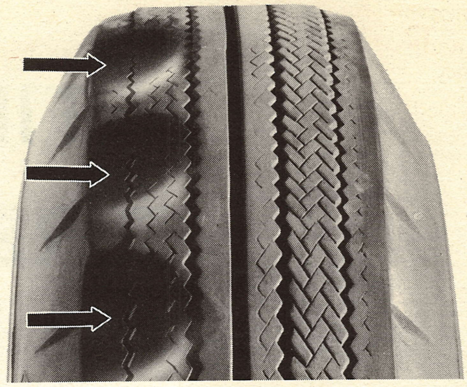
Basically tire valves have changed very little since they were first introduced. Details of a tire valve such as used in a tubeless tire are shown in Fig. 49-2. The inner valve or core acts as a check valve for the air, but positive sealing is provided by the valve cap which contains a soft rubber washer or gasket. It is this gasket, pressed against the end of the valve stem which seals the air in the tire. The careless practice of operating tires without the valve cap should therefore not be followed. Without the valve cap in place, there is usually a slow seepage of air from the tire with the result that the tire will be operated in an under inflated condition.



49-2. Showing location and details of tire valve in rim of tubeless tire.

TIRE WEAR

Under inflation, rapid stops, fast acceleration, misalignment, and unbalanced conditions, will seriously reduce the life of a tire. Road surface will also affect tire life. Sand and gravel roads will wear tires quickly, whereas concrete and asphalt surfaces aid in promoting maximum tire life.



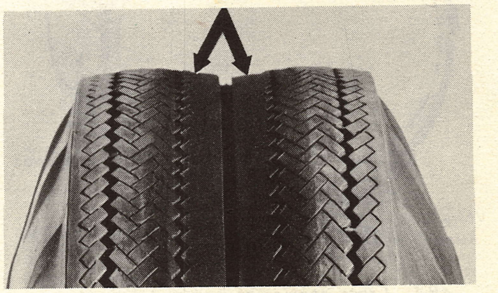
49-3. Spotty type wear which results from a combination of causes including under inflation and misalignment.

In addition to normal wear in which the tire tread is worn evenly and smoothly, other types of tire wear include:

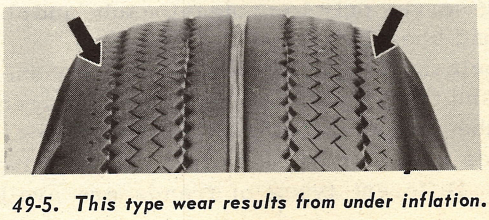
1. Spotty wear
2. Over inflation wear
3. Under inflation wear
4. Toe-in wear
5. Toe-out wear
6. Camber wear
7. Cornering wear

Fig. 49-3, shows a condition of spotty wear. This condition results usually from a combination of conditions to which the design of the particular tire tread contributes. Under inflation and incorrect camber are the main factors, along with excessive toe-in or toe-out.

Over inflation causes tires to wear excessively at the center of the tread surface as illustrated in Fig. 49-4. In addition, there is usually a little wear on the outer edges of the tire. This causes early failure at the center



49-4. Over inflation caused this type of wear.

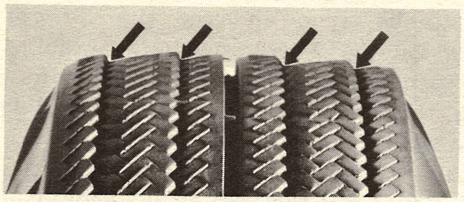


49-5. This type wear results from under inflation.

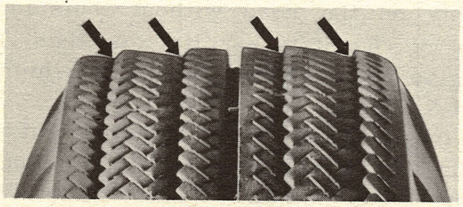
ribs and also breaks in the tire wall.

Wear due to under inflation is shown in Figs. 49-5 and 45-9. This is characterized by excessive wear on the two tread ribs adjacent to the inner and outer shoulder ribs. In many cases, under inflation also causes the spotty wear shown in Fig. 49-4.

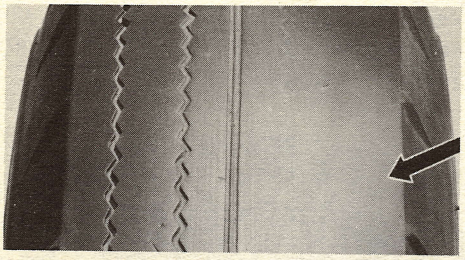
The amount of toe-in or toe-out is one of the most important factors governing tire wear. Unless the toe-in is correct, the tires will have a scrubbing action on the road surface, and excessive wear will result. Fig. 49-6 shows the wear due to excessive toe-in, and Fig. 49-7 shows wear due to toe-out condition. Toe-in wear produces a feather-like edge on the inner edges of the tread ribs, and can usually be felt by rubbing the hand over the face of the tire. The wear resulting from toe-out is of the reverse type, with the feather edge being produced on the outer edges of the tread ribs.



49-6. Excessive toe-in caused this type of wear.



49-7. Excessive toe-out caused this type of wear.

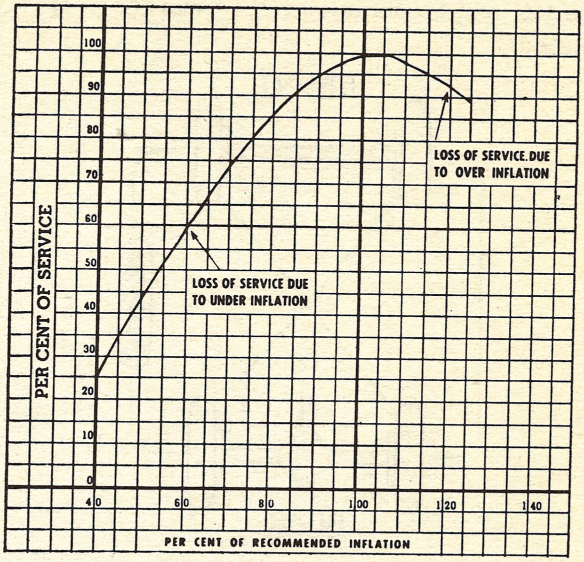


49-8. This type of wear results from incorrect camber.

Excessive camber will produce wear such as is illustrated in Fig. 49-8. If there is too much camber, the wear will be on the outer ribs, and if the camber is negative, the wear will occur on the inner side of the tire tread. If there is excessive wear on both the inner and outer areas of the tread, it is probably caused by excessive skidding on turns.

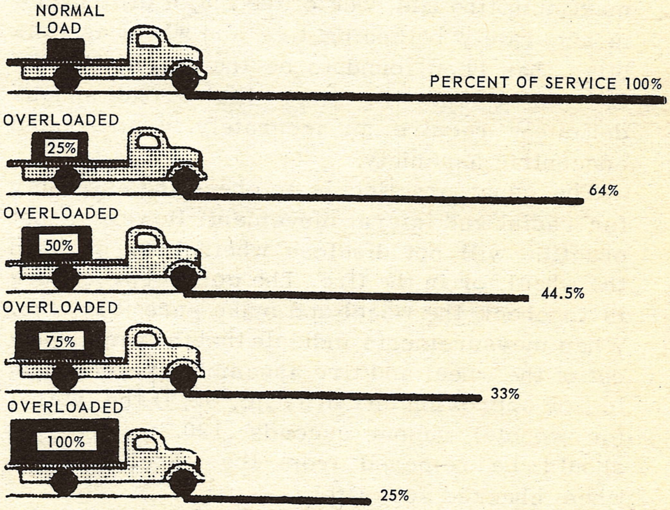
It should be pointed out when considering tire wear that the wear usually results from a combination of conditions.

Tires wear at a different rate on all four wheels due to driving conditions, the weight of the vehicle, the power on the driving wheels, the crown of the road, the alignment of the wheels, overloading the vehicle, Fig. 49-10, tire inflation, and probably most important of all, the driving habits of the driver.



49-9. Showing how tire wear is affected by under inflation.

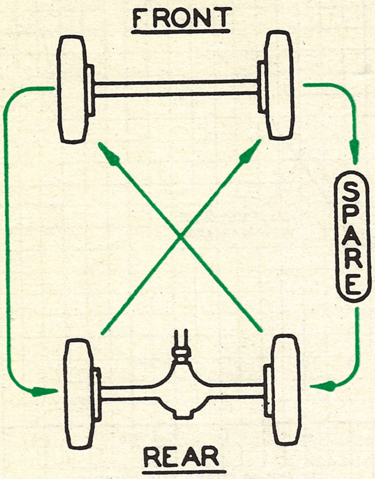
Fast starts, quick stops, high speeds, and taking turns at high speeds, all take their toll of tire life. Conservative driving habits promote maximum tire life and economy.



49-10. Overloading a vehicle reduces tire life.

TIRE ROTATION

In order to evenly distribute the wear of tires and help to obtain the maximum tire life, manufacturers recommend that tires be rotated from one wheel to another every 3000 miles. The generally accepted plan for rotating tires is shown in Fig. 49-11. This plan includes the use of the spare tire. Up to 20 per cent more tire life can be obtained if the tires are properly rotated.



49-11. To insure maximum tire life, the position of the tires on the vehicle should be rotated every 3,000 miles.

TIRE TRUING

As was pointed out in the chapter on wheel alignment, it is important that wheel and tire assembly be accurately balanced, in order to obtain satisfactory steering conditions. Such balance is also necessary in order to obtain maximum tire life. One of the major difficulties in accurately balancing tire and wheel assemblies, has been found to be the eccentricity of the wheel and the tire. High road speeds definitely require an accurately balanced and concentric assembly.

The usual practice is to check the assembly for radial and lateral movement. However, that practice will not disclose whether error is in the wheel, or in the tire. The correct procedure is to check the wheel and make sure it is true. When measurements indicate that the radial runout of the wheel and tire assembly exceeds .090 in., or approximately 3/32 in., or, if the lateral (or wobble) runout exceeds .120 in., the tire should be removed from the wheel and the wheel checked separately.

Referring to Fig. 49-12, the radial runout at each point indicated by "A" and "C" should not exceed .045 in., and the lateral runout when checked at points "B," should not exceed .060 in.

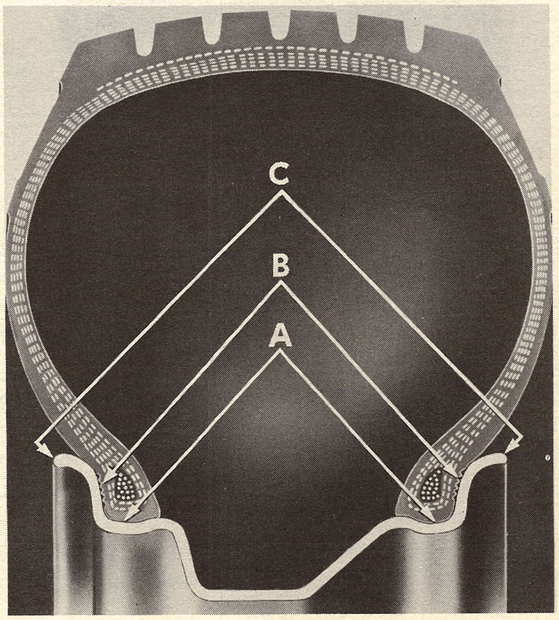
When checking a wheel for runout, it should be mounted on a hub that is free to rotate, but tight enough to prevent wobble. An accurate dial indicator should be used, and attached to a firm surface to insure accuracy of measurement.

When studying the problem of wheel and tire balance it must be remembered that unbalance and out-of-round are two separate conditions. An out-of-round assembly can be balanced, but tire thump on a smooth road will be evident. The reverse is also true. A perfectly round tire and wheel assembly can be out of balance, and an annoying thump will be evident when the car is driven.

In order to provide smooth riding, and obtain full mileage from the tires, it is essential that wheel and tire assembly be concentric and balanced. If the wheel has been checked and found to be true and the tire is correctly mounted on the wheel and the assembly is still found to be eccentric, then authorities advise buffing the tire tread so that it will be concentric with the center of rotation.

At first, it would seem that buffing rubber from the tread of the tire would shorten its life. Actually its life is extended as it will roll smoothly on the road without thumping. The amount of runout is usually less than .125 in. Buffing is not recommended, if the high spots exceed 7/32 in.

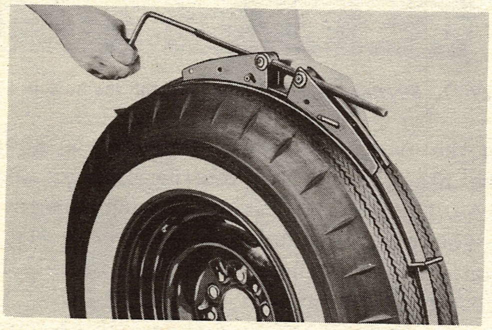
The increase in tire life results from the fact that the tire being a true circle and concentric with the wheel spindle will roll smoothly along the road. Consequently, there will be no bouncing and flexing as would be the case with an out-of-round assembly. Flexing increases tire temperature, which is one of the greatest enemies of tire life.



49-12. To insure true running, rims should be checked for lateral and diametral runout.

MOUNTING TIRES

The general procedure for mounting tubeless tires is to place the casing on the rim so the beads are resting uniformly on the bead ledge and quickly apply a large volume of air. This forces the bead over the bead seat and against the flanges, where the air seal for the tire is obtained. Some authorities advise using a lubricant on the tire bead which aids in slipping the tire onto the wheel and also helps insure a leak proof seal between the tire and the rim. The detailed procedure for mounting the tire is as follows:

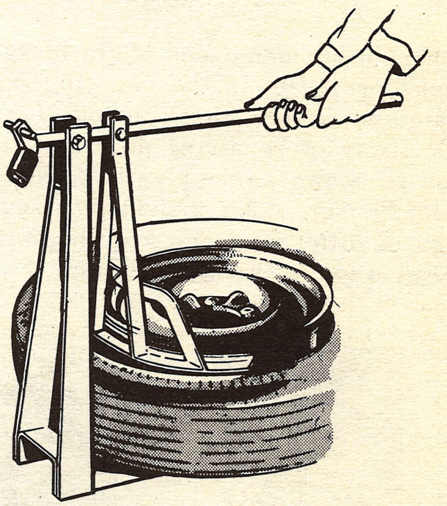


49-13. To spread the bead against the tire rim, special equipment is available.

1. Mount the tire on the wheel. This operation is greatly simplified by using some of the equipment that has been designed for that purpose. If such equipment is not available, the tire bead can be levered over the wheel rim by means of tire irons of the lever type.
2. Remove the valve core from the tire and inflate the tire. The sudden rush of air (unrestricted by the valve core) should force the tire beads against the bead seats on the wheel rim. If the beads do not contact both bead seats, then the beads must be spread by means of equipment such as shown in Fig. 49-13. If such equipment is not available, a simple rope tourniquet passed around the circumference of the tire can be used.
3. When the beads have been forced out to contact the seats, again apply air pressure, but only enough to seat the tire beads. Remove constricting equipment, and install valve core and inflate tire to 10 to 15 lb. pressure. Check position of tire in relation to rim, making sure that it is concentric. To assist in this check, tires have a ring molded on the tire side wall. This should be concentric with the edge of the wheel rim. If it is not concentric, the tire and wheel assembly can be jounced on the floor until the tire is correctly mounted. Then inflate the tire to the recommended pressure.

When mounting or removing tubeless tires, it is important that the tire irons and other tools that are used are smooth and free from burrs and other roughness. Such defects will score the tire bead and cause leaks to occur. Similarly, before mounting the tire, the rim should be carefully checked to make sure it is smooth. Any dirt or rust should be removed from the bead seats.

When using tire irons to lever the tire over the wheel rim, take small "bites" with the tire iron to avoid damaging the rim seal ledges, and pry the bead over the rim flange so that the section nearest the valve stem will be applied last. To break the tire bead loose from the rim, equipment similar to that shown in Fig. 39-14, should be employed.

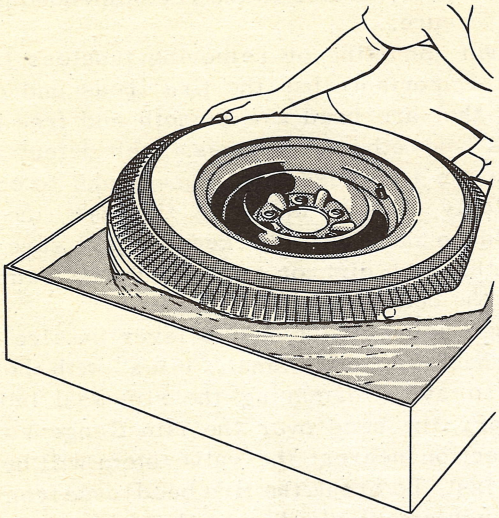


49-14. Method of breaking loose tire bead from wheel rim.

TIRE REPAIRS

In most cases of leaks in tubeless tires, it is not necessary to remove the tire from the wheel. In fact the repair can be made without removing the tire and wheel assembly from the vehicle. The puncturing object, when found can be removed from the tire and the repair made by using the plug method or some similar method of repair.

If the tire is flat, reinflate and listen for a fast leak. If the leak is too slow to be found by sound, remove the wheel and tire assembly and submerge it in a water test tank, Fig. 49-15. If a test tank is not available, apply a coating of soap solution, making sure to cover the entire surface of the tire, valve stem and juncture of the tire and rim flange. Any leak will appear in the form of soapy bubbles.



49-15. Immersing a tubeless tire in a test tank to check it for leaks.

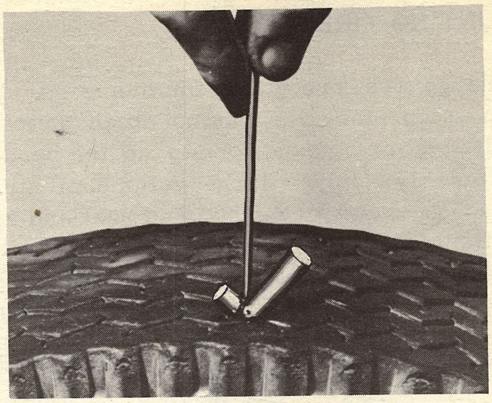
There have been cases of rim leakage through cracks or rivets in the rim. If the leak is not located in the tire, check the rim for defects.

One way of repairing punctures in tubeless tires is known as the plug method, Figs. 49-16 to 49-19 incl. A kit provides an assortment of plugs of different sizes, together with a needle inserting tool and repair cement.

REPAIR CEMENT

49-16. Forcing cement in tire hole, before installing repair plug.

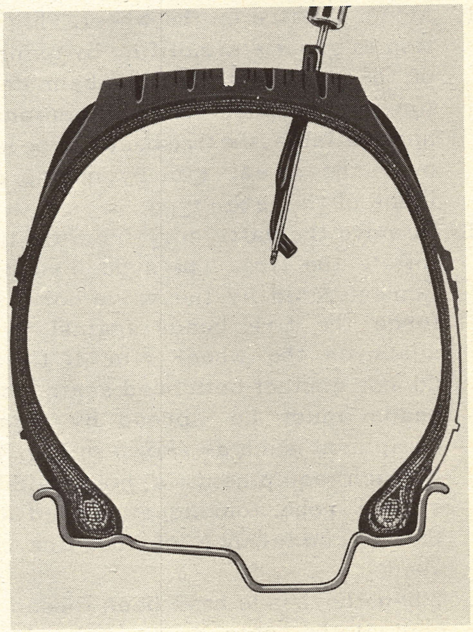
After removing the puncturing nail or other object from the hole, dip the needle in repair cement, and probe into the puncture to locate its direction, Fig. 49-16. Repeat until the hole is well covered with cement. Do not force the needle into the hole if it seems blocked as that may enlarge it, making it more difficult to seal. Select a plug that is approximately twice the diameter of the hole. Dip the plug and needle end in cement and immediately insert in hole in tire with a firm and steady motion, Fig. 49-17.



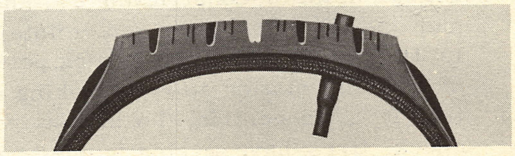
49-17. Starting the repair plug through the hole in tire.

Push the needle and plug in, until the short end of the plug snaps through the tire, as shown in Fig. 49-18. Remove the needle by pulling straight out. The plug will unhook automatically. Trim the outer end of the plug approximately 1/8 in. above the tread surface, Fig. 49-19.

For larger holes, and those which cannot be repaired by the plug method, it will be necessary to repair the tire casing from the inside. After removing the tire from the wheel and the damaged area is located, spread the tire apart using special spreaders, one type of which is

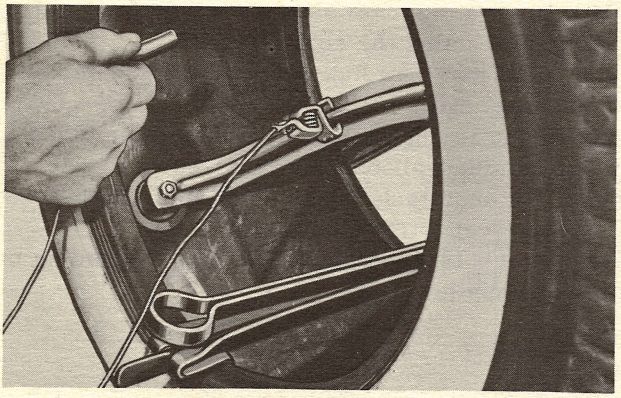


49-18. Repair plug after being forced through hole in tire.



49-19. Repair plug cut off close to surface of tire tread.

shown in Fig. 49-20. This will provide easy access to the damaged area. Clean the area surrounding the injury with a rasp. Fill the hole with cement or tire compound. Again clean the inside area with a hand buffer or wire brush. Apply cement around the area and allow to dry. Apply a cold patch to the cemented area, pressing it down firmly using toothed wheel provided with the patching kit.



49-20. Tire spread apart for inspection and repair.

Punctures can also be repaired from the inside of the tire using a hot patch method. The procedure is the same as described for a cold patch, except cement is not applied to the buffed area. Instead the hot patch is clamped in position and the patch is ignited. After the patch is cool, the tire is mounted and inflated.

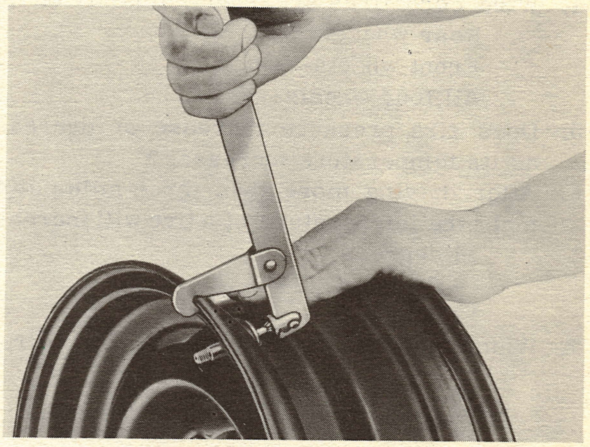
Plugs can also be applied from the inside of the tire. In such cases the plug has a large flat head covering an area of an inch or two.

VALVE REPLACEMENT

Should air leaks occur around the valve stem, it is necessary to install a new valve stem assembly, Fig. 49-2. This is easily accomplished by means of a special lever type tool as shown in Fig. 49-21.

RETREADING AND RECAPPING

The life of a tire can be materially extended by either recapping or retreading the tire. Recapping means adding a top strip (called camelback) of synthetic or reclaimed rubber to the buffed and roughened surface of a worn tire. Retreading means adding full width new rubber to the worn tire. The terms are used rather loosely and interchangeably in the tire industry, but a retread is ordinarily a better and more thorough job since new rubber is bonded shoulder to shoulder of the tire.



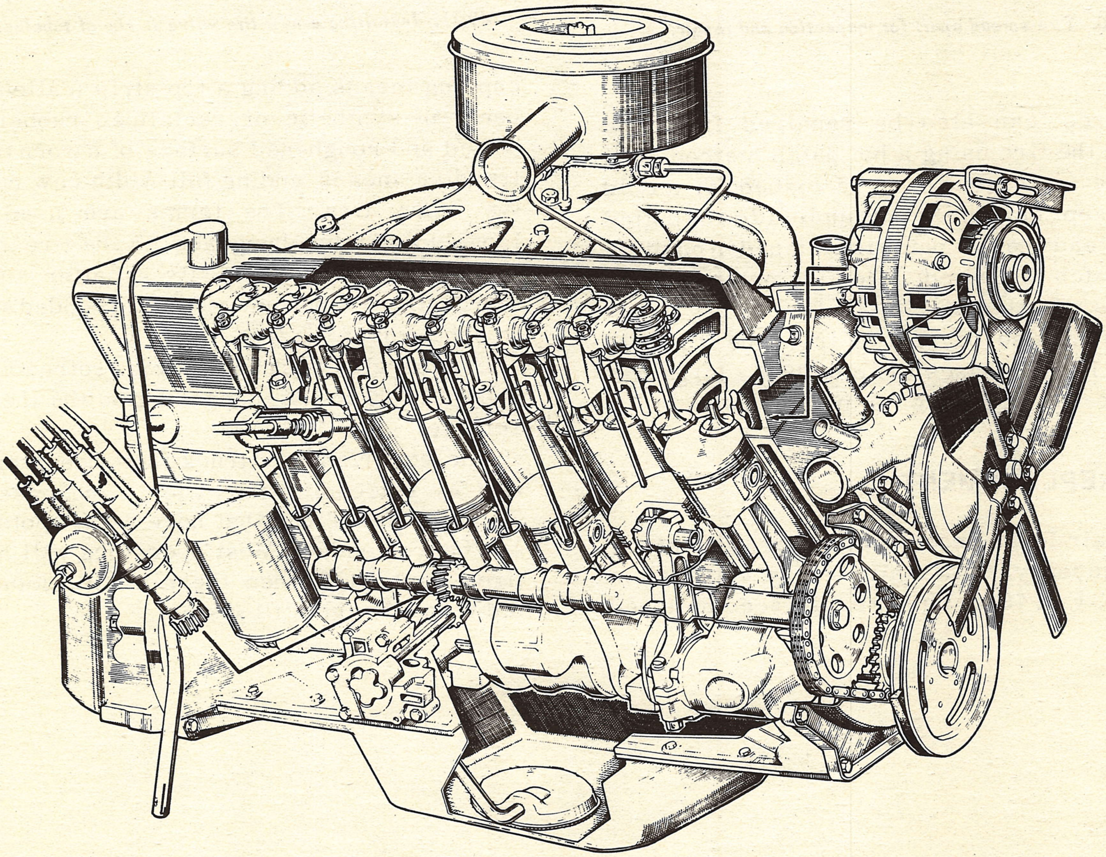
49-21. Installing a new tire valve in rim of tubeless tire.

In general, tires are ready for retreading after about 23,000 miles, depending on the the type of service.

The experience of truck fleet operators show that by retreading tire life is increased about 75 per cent. Tires that have weak spots should not be retreaded. Most operators will have the tires retreaded when there is still some of the old tread design still visible.

QUIZ - TIRES, TIRE SERVICE

1. What are the advantages of the pneumatic tire?
2. List five different types of tire treads.
3. Only natural rubber is used in the manufacture of tires. True or false.
4. Wire cord tires are used primarily on bus
   Rear wheels----
   Front wheels----
   All four wheels----
5. Does tire pressure increase or decrease as its temperature increases?
6. After driving more than three miles at 40 mph, the temperature of a tire will increase
   4 degrees
   6 degrees
   12 degrees
7. Which provides positive sealing for a tire?
   a. the valve cap b. the valve core
8. Taking turns too fast (cornering) will wear tires at
   a. the center of the tread
   b. on the outer edges of the tread.
9. Describe the wear on tires resulting from excessive toe-in.
10. Draw a diagram showing a plan for rotating tires, using the spare tire.
11. How much radial runout is permitted on a wheel rim?
12. What is the purpose of the ring molded in the side wall of the tire?
13. If a test tank is not available, how would you test a tire for leaks?
14. Which is considered better, retreading or recapping?



225 cu. in. 6-cylinder aluminum engine used by Dodge Lancer.

BODY REPAIRING, REFINISHING

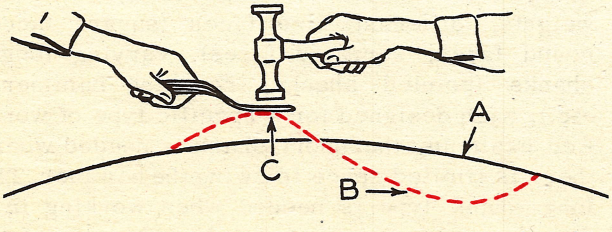
Regardless of how badly a body panel or fender has been damaged it can be straightened. All that is required is the necessary tools and equipment, plus the required skill on the mechanic's part. However, in cases of severe damage, it may be quicker and more economical to replace the part than to repair it.

Straightening sheet metal is much easier than it appears to be. With modern equipment and tools the work proceeds rapidly. The necessary skill can be attained in a relatively short time by practicing on junked fenders, doors or panels.

The ease and speed with which sheet metal is straightened is largely dependent on starting the repair work in the right way. When done correctly, not only is the amount of dinging, as the process is called, reduced, but also, stretching of the sheet metal will be kept to a minimum and the amount of hand filing and sanding will be materially reduced.

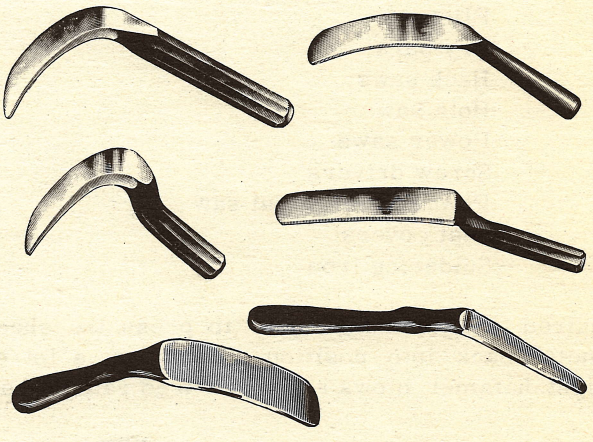
When straightening a wrinkled panel, the damage should be removed in the reverse order in which it was made. When a collision occurs there will be a major depression in the panel followed by a buckled area and then by a series of ridges.

Without proper instruction, a mechanic will usually apply pressure at the spot where the panel was struck first and where it is depressed the most. The correct method is to apply pressure at the ridge furthermost from the point where the body was struck first. It is not unusual when this is done that the entire damage will spring back into its original position.



50-1. *To remove a dent, pressure is first applied at the ridge farthest from where the panel was struck.*

To make this procedure clear, assume that the original form of the panel is shown at (A) in Fig. 50-1. The point (B) is where it was struck and (C) is a ridge formed last and consequently should be treated first. Place a spoon, Fig. 50-2, on top of the ridge and strike it with a mallet or hammer. Follow the ridge with the spoon and mallet and it will be found that as the ridge is removed, the major depression at (A) will also spring back so that it conforms very closely with the original contour of the panel.



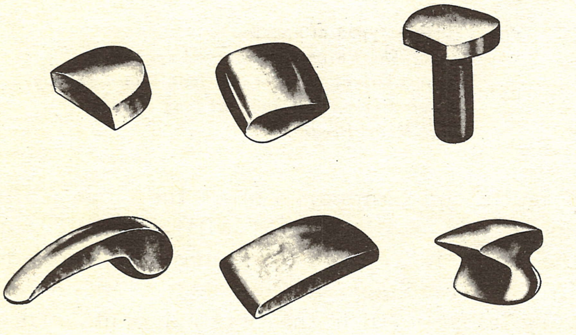
50-2. Various types of spoons.
Upper: Short elbow and curved spoons.
Center: Offset straight and long elbow spoons.
Lower: Curved flat and flat long spoons.
(Duro Metal Products)

The few remaining dents are then removed with a dolly block, Fig. 50-3, and hammer. Select a dolly block with a face of the same general curvature as the panel. Hold it under the panel and strike the high point of the dents with a dinging hammer. In this way the dolly block acts as an anvil. The blows from the hammer should be light, as heavy blows will tend to stretch the metal by making it thinner. All that is re-

TOOLS REQUIRED IN BODY REPAIR WORK

- Hand fender-straightening tools
- Bench for straightening panels and doors
- Bolt cutters
- Car horses or trestles
- C-clamps
- Center punches and drifts
- Cold chisels
- Air compressor
- Creepers
- Drill sets
- Bolt extractors
- Fender covers
- Fire extinguishers
- Bench grinder
- Hammers
- Sledge hammers
- Chain hoist
- Garage jack
- Hand jacks
- Lift
- Metal shears
- Pliers
- Pry bars
- Hack saws
- Hole saws
- Power saws
- Screw drivers
- Power sheet metal saw
- Seat covers
- Soldering iron
- Steel rule
- Stepladder
- Tap-and-die sets
- Headlight testers
- Radiator repair equipment
- Thread chasers
- Tire repair equipment
- Towing and wrecking equipment
- Complete wrench sets
- Electric drills (1/4, 1/2, & 3/4)
- Trouble light
- Paint sprayer
- Welding outfit
- Sander and polisher
- Glass cutting & grinding equipment
- Arbor press
- Frame straightener
- Wheel-aligning gauges
- Wheel pullers
- Bench vise
- Workbench
- Wheel balancer
- Wheel straightener
- Striping brushes
- Drying lamps
- Spray booth
- Ventilating fan
- Power fender straightener
- Body-straightening jacks
- Panel clamping-repair units

quired of the hammer is to press the sheet metal back into position. Therefore, a lot of light hammer blows should be used rather than attempting to use a few heavy ones. If the metal is stretched, a large bulge will result which will require shrinking. Furthermore, the hammer blows should be at the rate of approximately 60 per minute, and the mechanic should "pull" the hammer as it strikes the surface of the sheet metal. In other words, the hammer is used so as to give a sliding or glancing type blow.

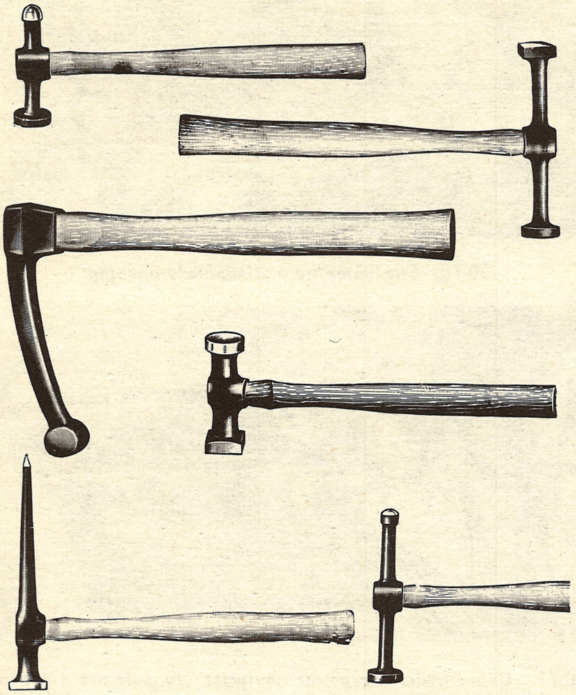


50-3. *Assortment of dolly blocks.*
Upper: Heel, utility and mushroom dollies.
Lower: Wedge, toe and general purpose dollies.

It is also important to note that when the dent raises above the surface of the dolly block, the hammer should strike the center of the dent. But if the dent is below the surface of the metal and toward the dolly, the dolly should be placed against the head of the dent and the hammer blows should be directed against the edge of the dent.

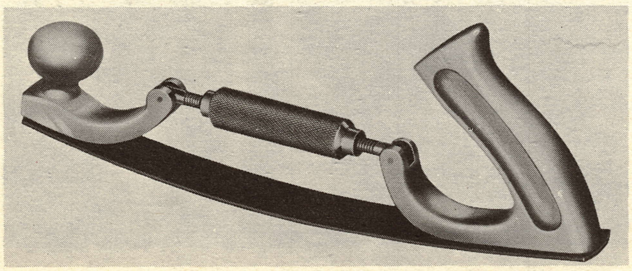
The hammer should be held loosely with the thumb along the top of the handle for better control of the bounce. There are many different designs of hammers, Fig. 50-4, different weights, different size faces (square faces, round faces, serrated faces), varying length shanks (pointed shanks, roughing hammers, etc.); each designed for a specific type of work. For example, the short shank is needed where there is limited space to swing the hammer. The long shank type is needed when working in a deep contour, the serrated face for shrinking metal, the tapered shank for working on moulding, etc. All are important and should be in every body man's kit.

Similarly, there are a large variety of spoons, Fig. 50-2, and dolly blocks, Fig. 50-3, each designed to make certain tough jobs easy. The spoons primarily are designed for use on polished surfaces; that is, the spoon is placed against the finished surface of panel and is struck with the hammer. They are occasionally used as a dolly, where space limitations prevent a mechanic from using a regular dolly. They are also used for prying a bulge in a door or trunk lid back into place.



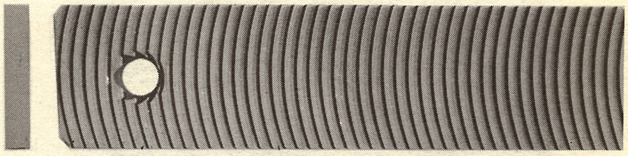
50-4. Two types of dinging hammers are shown in the top row. Two roughing hammers are shown in the center. On bottom row at left is a pick hammer and on right another dinging hammer.

Dollies vary in weight, shape, and contour so that they will conform to the curve of the panel and can be used in cramped quarters. Some provide grooves for working beads and moulding. Skill in using these tools can be quickly attained by working on junk panels and fenders. The important point is to have a wide selection of spoons, dollies and hammers, so that all types of body work can be handled.



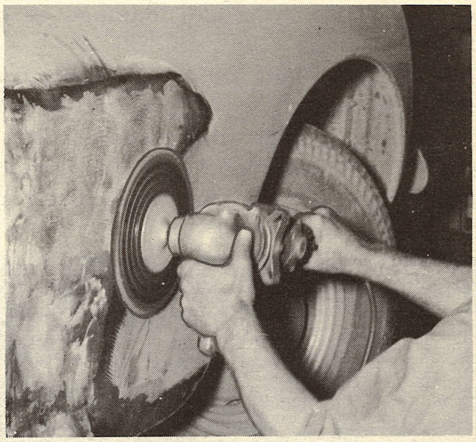
50-5. Flexible type body file holder.

As the dents in the body panel are gradually removed, the mechanic should occasionally rub his hand over the surface. This will help determine those spots which require further straightening. Then when that method fails to show any high or low spots, the body file, Figs. 50-5 and 6 should be used. Only light cuts should be made, and the mechanic should remember that the purpose is not to remove metal, but to show the areas that require further attention with the dolly and hammer.



50-6. Flexible milled tooth body file for use in holder shown in Fig. 50-5.

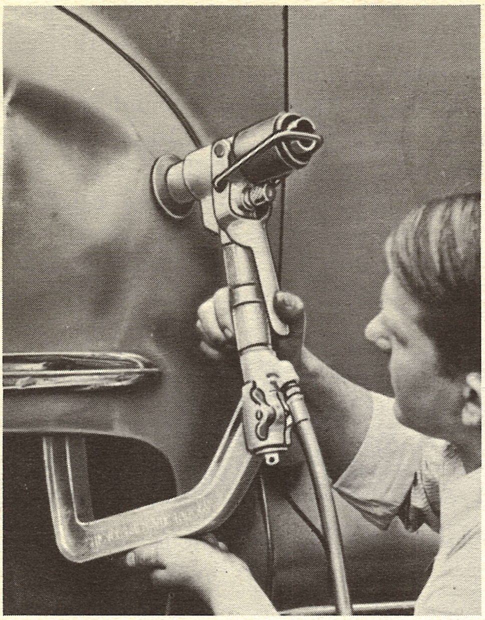
Finally a sander, Fig. 50-7, is used, first to locate the few remaining irregularities, and last to remove any slight roughness that cannot be removed with the dolly.



50-7. Using a disk sander.

POWER STRAIGHTENING

While the hand dolly and dinging hammer are used extensively, there is a growing trend toward the use of power dinging equipment, Fig. 50-8. These tools are available from a number of different manufacturers. Both electric and pneumatic types are available. On panels where they can be used, considerable time can be saved. In addition to the advantage of speed, such tools will not stretch the metal as much as conventional dolly and hammer work. The amount

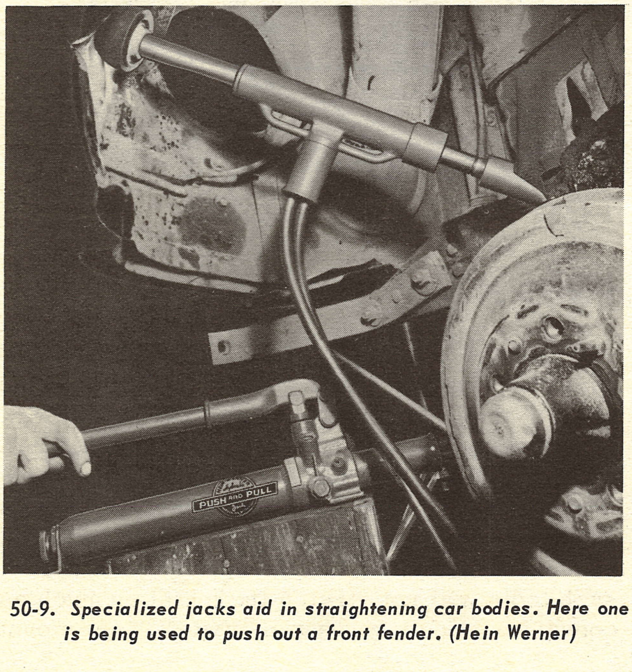


50-8. Using a pneumatic power fender straightener.

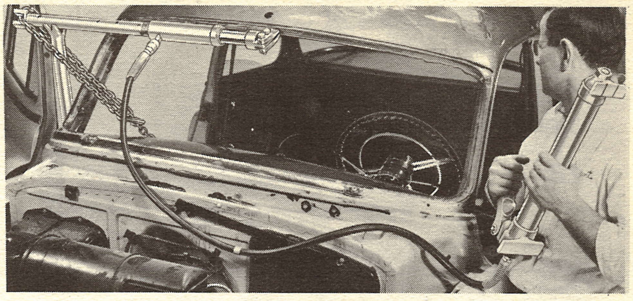
of filing or sanding required to finish the fender or panel is usually less than required with hand methods.

There is occasional trouble in using power operated dinging hammers on car tops and other large areas where damage is more than 18 or 20 in. from edge of panel. However, on areas where damage is close to edge, damage is quickly removed.

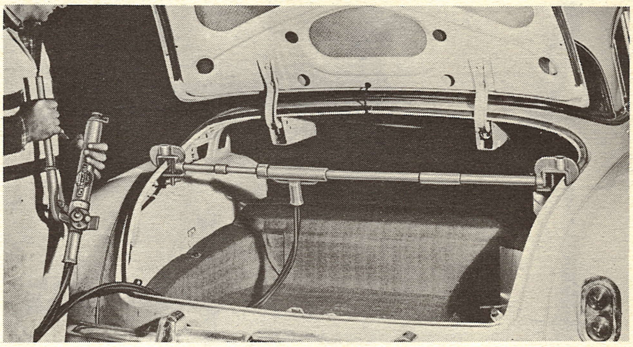
Another important piece of equipment for straightening bodies is the specialized hydraulic jack, Fig. 50-9, with fittings and accessories designed to remove dents and to push or pull badly damaged panels and other car parts back into position. In addition to rough straightening of panels, this equipment has many other uses, such as straightening diamond-shaped door and window frames, squaring bodies, correcting door curvature and frame and bumper work, Figs. 50-10, 11, 12 and 13.



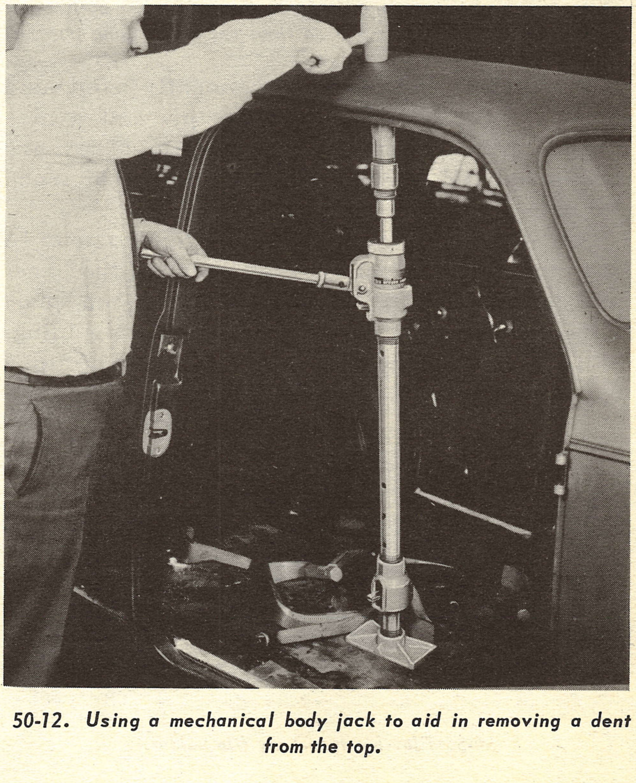
50-9. Specialized jacks aid in straightening car bodies. Here one is being used to push out a front fender. (Hein Werner)



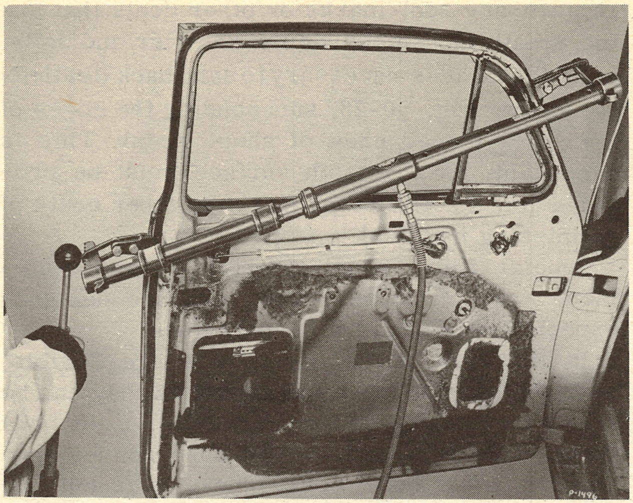
50-10. Straightening a windshield opening.



50-11. Using hydraulic power equipment to pull the sides of a trunk opening into alignment.



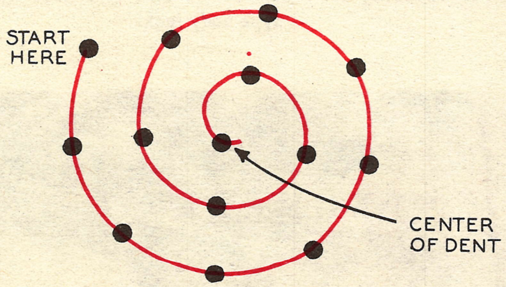
50-12. Using a mechanical body jack to aid in removing a dent from the top.



50-13. *Straightening a door with special power equipment. (Blackhawk)*

When using such hydraulic equipment to take a dent out of a panel, the same principle as is used with hand dollies should be followed. In other words, pressure is first applied at the outer edge of the dent. Then proceed and work around the dent, gradually approaching the center, Fig. 50-14. The work is then completed with a hand dolly or a power straightener.

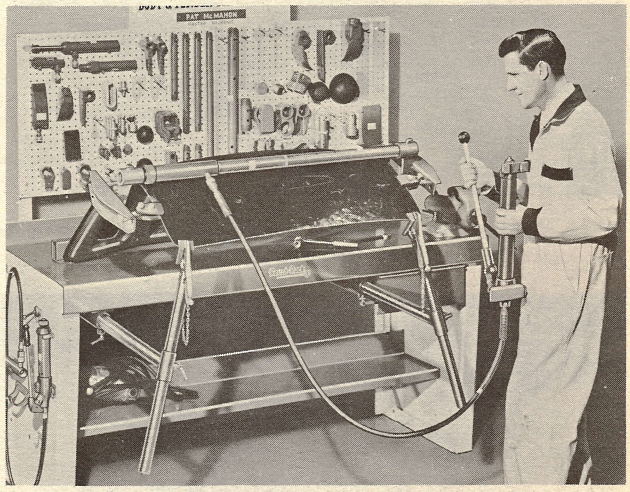
Before starting to straighten a panel it is important to clean all the dirt from both sides. This can be done by scraping or by heating it lightly with a torch. Similarly, it is important to remove any undercoating or sound deadening material from the fenders and panels. Mud and grit adhering to panels will mar the surface of the straightening tools, and undercoating will, of course, make straightening difficult.



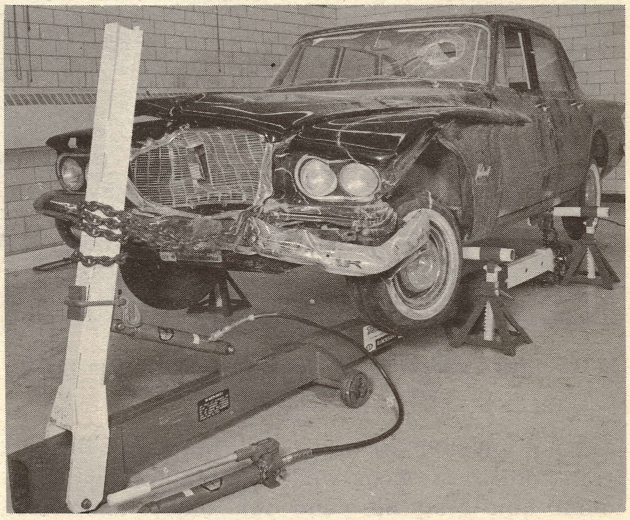
50-14. *When using the hydraulic jack type of straightening equipment on a dent, start at the outer edge and work in a spiral toward the center.*

Another important piece of equipment that is of value in straightening doors and other panels is the straightening bench or table, Fig. 50-15. The damaged door or panel is attached to the bench with suitable clamps. In this way, the part is held rigidly and in such a position that it can be easily straightened with hand or power tools.

Another type of power straightening equipment, which is available under various trade names such as "Pulldozer" Fig. 50-16 is designed to pull the crumpled metal back into its original position. As shown in the illustration, one end of the equipment is anchored to the chassis of the vehicle, while the other is attached to the damaged area. Operation of the jack will then pull the damaged area forward into alignment. The job is completed with the usual ding work. When pulling the damaged area forward, heat is often used in cases of severe damage.



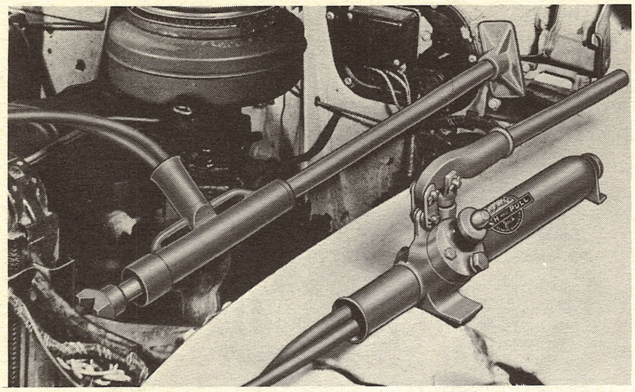
50-15. *Special bench for holding tools and equipment. Damaged panel can be secured to bench while being straightened.*



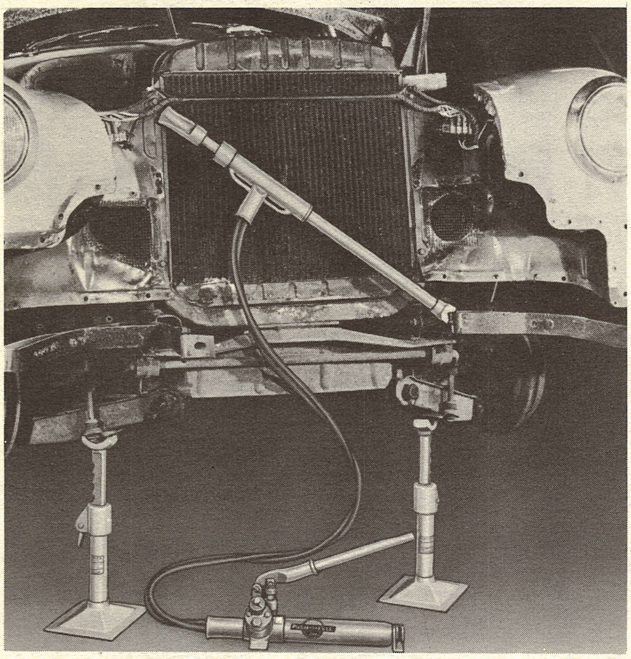
50-16. *Using a Pulldozer to pull crumpled panels into alignment.*

POWER STRAIGHTENING METHODS

Modern power straightening equipment not only speeds body repairing but also does many jobs which are otherwise virtually impossible. There are an infinite number of different body repair jobs which such equipment can do. A few of them are shown in Figs. 50-17 to 22 incl. It is, of course, difficult to make comparative time studies on body work, but as nearly as can be ascertained, savings of 50 per cent are not unusual when special equipment is used.



50-17. *Straightening a radiator support with hydraulic straightening equipment. (Hein-Werner)*



50-18. *Direct push with special equipment to align radiator core support. (Hein-Werner)*

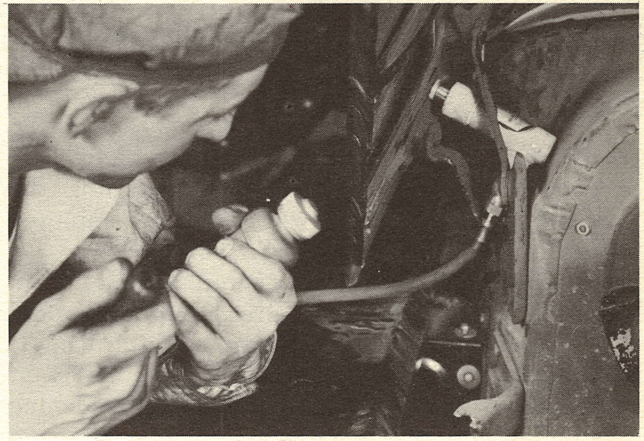
In addition to body work, straightening equipment can also be used for other shopwork, such as straightening, pulling, and pushing. By cutting time and saving labor it brings added profits to the shop.

BODY FILES

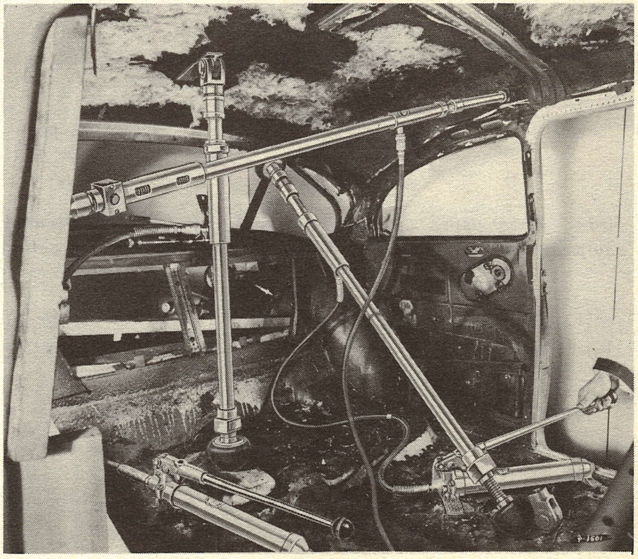
After the sheet metal has been made as smooth as possible by means of a hammer and dolly, the next step is to sand or file the surface to remove any tool marks or other dents that are too small to remove by the hammer and dolly. In addition, it is necessary to sand back (feather) the paint, Fig. 50-23, surrounding the edges of the straightened area of sheet metal. This is important, as a smooth surface must be provided for the filler, primer and other coats of refinishing material.

Special files, sanding materials and equipment are, of course, used and are designed especially for automotive body work.

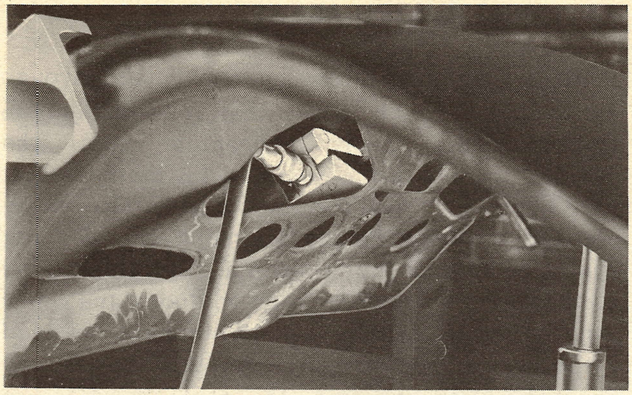
In the case of the files, these are flexible, so that when used in a special holder they can be arced to conform to the curvature of the body panel. The teeth are curved and are designed especially for body work. These files cut fast and will not load up when used on the sheet iron of the body or a solder-filled dent.



50-19. *Pressing out a dent in the side of a hood with special type body jack.*



50-20. *Reshaping car top with Porto-Power equipment. Two setups exert pressure on left side and rear top body section, while third setup pushes out dents in center of car top.*



50-21. Popping out dent in deck lid with hydraulic spreader. (Blackhawk)

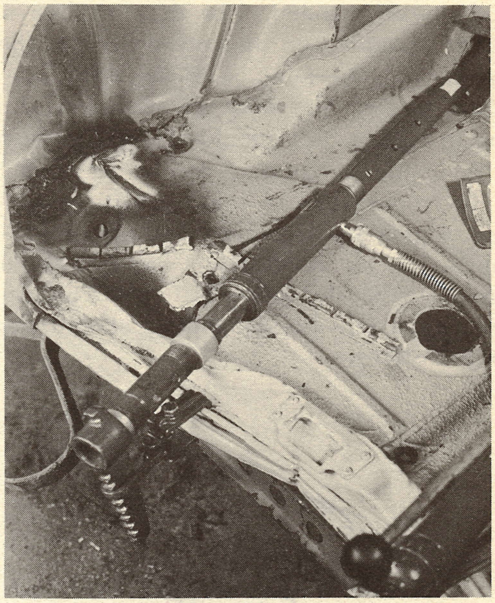
Conventional machinist files cannot be used for body work. As previously pointed out, some mechanics prefer body files, particularly for use in locating the high and low spots while proceeding with the dinging. Whether used for that purpose or for the final smoothing, the surface is filed first in one direction and then in the other, at approximate right angles. On the return stroke the file should be lifted from the surface being filed. This will not only produce a smoother surface but will also prolong the life of the file, as dragging the file along the surface of the metal on the return stroke will tend to dull the file teeth. It is important to note that special body files can be resharpened.

POWER SANDING

Because a sanding disk is flexible, it will follow the larger indentations in a body and for that reason is used to locate the high and low spots only when the straightening process has been nearly completed. Of course, for the final finishing of the metal surface, it does an excellent and fast job. In addition to being used for sanding the metal surface, it is used to remove the paint or other refinishing material surrounding the damaged area. This is known as feather edging.

Before sanding a panel, it is important to select the disk having the correct abrasive for that particular surface. In this connection many shops use three different grits to prepare the surface for repainting. They first use a 16-grit disk to remove rust and loose paint and for cutting down solder spots. This is followed with a 24 grit disk for surfacing the metal, restoring contours, and for cutting down welds. Then for final finish, a 50 grit disk is used.

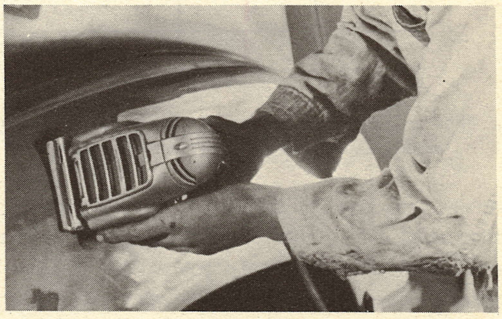
Instead of three different grits, some shops prefer to use a 24 grit disk as an all-purpose sander. However, a manufacturer of sanding disks claims that for comparable jobs the three-disk method will require 11.7 minutes to complete the work while 15 to 18 minutes will be required for the single abrasive method.



50-22. Using hydraulic straightening equipment to straighten damaged floor of car.

For sharply curved surfaces which cannot be reached by conventional sanders, special cone-type sanders are available. These sanders will reach such curved surfaces as are found around headlights, fender joints, back deck panels, etc.

After the surface of the panel has been thoroughly sanded, it is necessary to sand the edges of the paint surrounding the area of the panel that has been straightened. Some body mechanics use a disk-type sander, others prefer an oscillating or block-type sander, while some still use hand sanding.

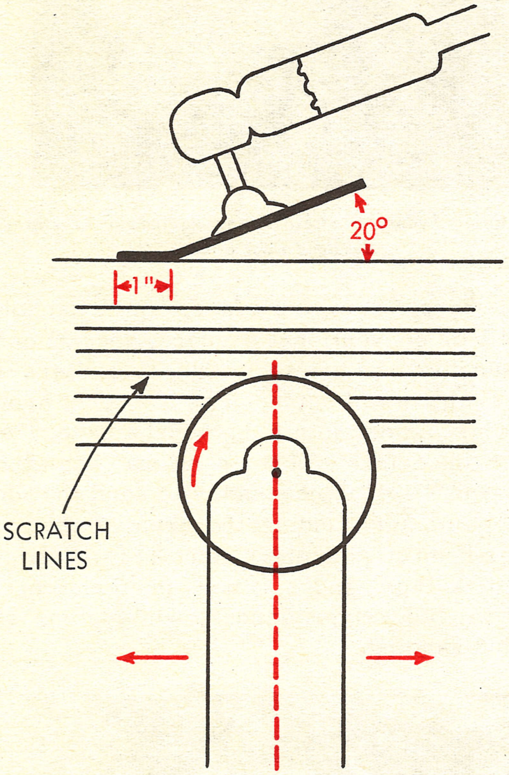


50-23. Feather-edging with a block type sander. Disk type sanders are also used for that purpose.

In disk feather edging, a 100-grit disk is usually recommended; 80 is used in the oscillating sander and for hand sanding too, with 220 grit being used for finished feather edging.

When disk sanding, it is important to hold the disk grinding machine at an angle of approximately 20 degrees to the work, Fig. 50-24. Sufficient pressure is applied so that about 1 inch of the disk is bent and is in contact with the surface being sanded. The disk sander should never be operated so the entire area of the disk is flat against the surface of the work, nor at an extreme angle. The disk grinder should not be swung in an arc, but should always be moved so that it is perpendicular to the scratch lines. This is important, as less conditioning is required to prepare the metal for priming.

Similarly, an oscillating sander should be operated so that the scratch lines will be approximately parallel. Hand sanding should produce the same effect.

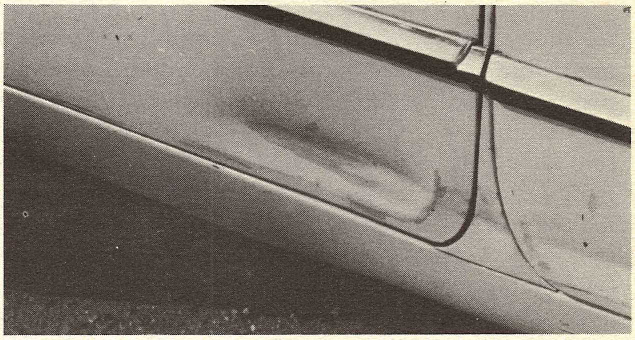


50-24. *When using a disk sander, it should be held at approximately 20 deg. to the surface of the panel.*

There are many different types and grits of sanding disks available, and the manufacturer's instructions should be followed as to their use. However, open grain disks are designed for paint removal where other disks would tend to load up. Closed grain disks are for use on base metal. The latter are available in grits from 16 (very coarse) to 180 (extremely fine), whereas, the open grain disks are available only up to 120 grit.

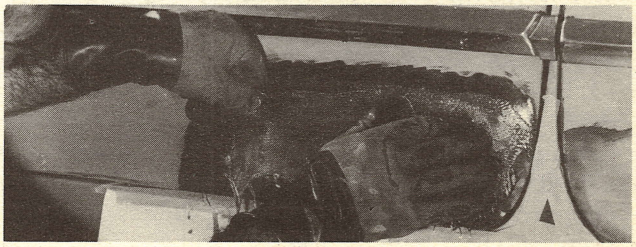
PATCHING RUSTED AREAS

When body panels have become rusted through or dented in such a way that it is difficult to remove dents, many mechanics repair the damage by one of the commercial methods that have been developed for the purpose. One of the popular methods consists essentially of using sheets of special fabric such as fiberglass. This method is used extensively on doors and other panels where heat and solder cannot be used without first removing the interior upholstery and trim. For example, the dent shown in the door, Fig. 50-25, could not be filled with solder as the heat would destroy the interior trim, unless the trim was first removed. With the fabric plastic method such additional work is not necessary.

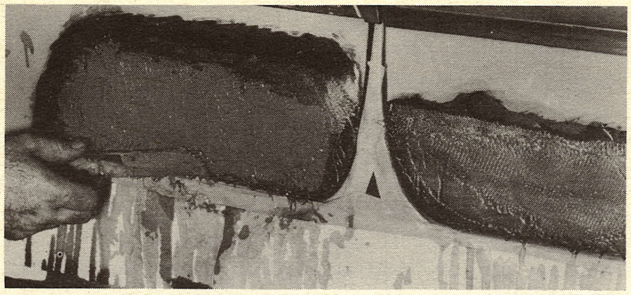


50-25. *Dents such as this can be filled with special body compounds or with fiberglass, without the need of removing the interior trim.*

The first step is to thoroughly sand the surface of the dent to remove all traces of rust, paint and other foreign material. The dent is then filled with resin-soaked fiberglass patches, the final patch being cut large enough to lap over the surrounding undamaged surfaces, Fig. 50-26. Epoxy metal solder is then applied, Fig. 50-27, over the last patch with a putty knife to build patch to final contour and to fill pits and indentations. After this has become thoroughly dry,



50-26. *After sanding the surface, sheet of fiberglass soaked in special solutions is used to fill the dent.*



50-27. *Epoxy metal solder is then applied with a putty knife.*

the surface of the epoxy solder is sanded, Fig. 50-28, and the job is ready for painting.

Another method is to use a body cement or plastic solder, Fig. 50-29. The material is first mixed according to the manufacturer's directions, and then applied as shown in the illustration. It is then sanded in the usual manner.

Naturally, details of making such repairs as have been described will differ somewhat with the various manufacturer's products. However, it is essential that the surface of the metal be thoroughly cleaned and sanded before making the repair. This is necessary in order to obtain proper adherence between the repair material and the sheet metal of the body.

This type of repair material sands well, is readily feather-edged, and the sanded surface is well adapted for all forms and types of paint. When properly applied and prepared, the final finish cannot be distinguished from the original body finish.

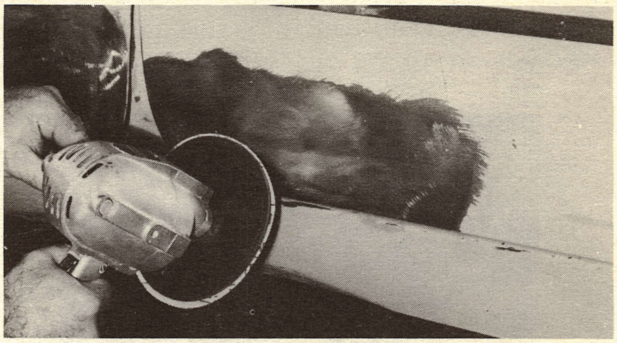
If the area to be repaired is small, the special body metal is all that is needed. In such cases it is usually applied with a putty knife or spatula. If the dents are deep, allow ample time for drying.

BODY SOLDER

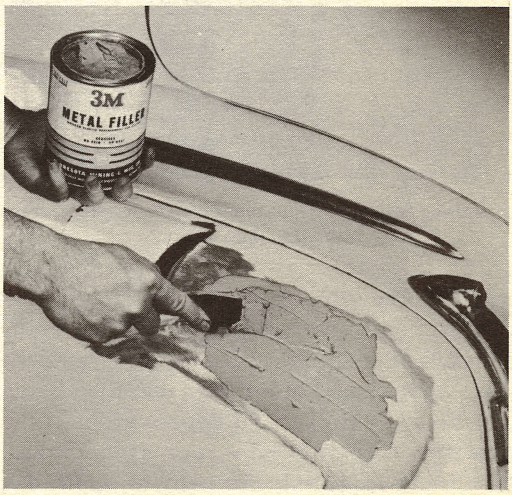
An early but still popular method of filling dents in automobile bodies is by means of solder. This is an effective and satisfactory method. Solder is used extensively for filling small dents and smoothing rough surfaces, which are difficult to straighten completely with a dolly block and hammer. Another use for solder is to form crushed drip mouldings and other contours which are difficult to restore to their normal shape. While solder can be used for filling large dents, most mechanics prefer to at least "rough out" the damaged surface. In that ways the amount of solder used is materially reduced.

Manufacturers provide solder of special formulas designed especially for automotive body repairing. This solder is correctly proportioned so that it is easily applied on vertical surfaces, can be sanded, and refinishing materials will adhere to it.

Before attempting to fill a dent with body solder the surface should be thoroughly cleaned to remove all paint, rust, and grease. This is important, as it is impossible to tin a dirty surface. To remove rust and paint, most mechanics use a No. 16 grit open coat paper and follow that up with a No. 24 grit closed coat. When the surface is clean, it is given a coat of flux and then tinned.



50-28. *After thorough drying the surface is sanded and made ready for painting.*

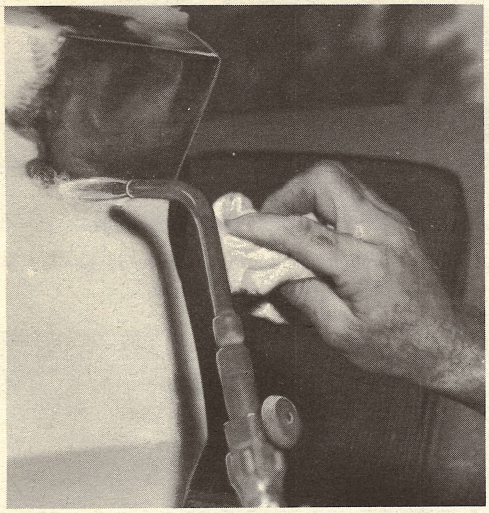


50-29. *Applying a special body cement or plastic solder to fill dents in a fender.*

Since the body metal is sheet steel, a flux designed for use on that metal should be used. Always follow the manufacturer's instructions if a commercial flux is used. However, many shops use a solution made from zinc dissolved in hydrochloric acid. The body panel surface is heated slightly and is then given a coating of the flux.

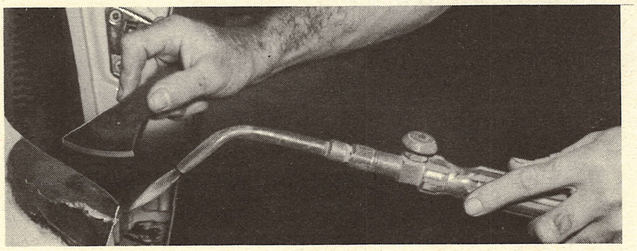
There are several different methods used by mechanics in tinning. Some use a conventional soldering iron. The solder is pressed against the body panel with the hot iron or torch, until it melts, after which the solder is distributed over the desired area by means of the soldering iron. Naturally, on large areas it will be necessary to apply additional quantities of solder until the entire surface is tinned.

Another method is to use steel wool or a piece of cloth to distribute the solder over the surface of the panel, Fig. 50-30. Here a few drops of solder have been melted by the torch so that they adhere to the panel. Then as more heat is applied, the solder becomes liquefied so it can be spread over the surface by using the steel wool. The steel wool method has the advantage that the solder can be brushed down into crevices, cracks and depressions.



50-30. Melting solder on the surface with a torch, preparatory to tinning the surface.

Once the surface has been tinned the body metal can be applied. As heat is applied to the body solder, it becomes plastic but not liquid, so that it can be spread with a paddle, Fig. 50-31. After some lead has been applied to the panel, the mechanic keeps the torch in motion over the area being worked. The distance of the torch from the panel varies with the size of the flame. A little experimenting will enable the mechanic to judge the distance the flame must be held from the work, and the speed at which it should be moved back and forth.



50-31. While keeping the solder soft with the torch, it is spread with a wooden paddle.

After the dent has been filled and the surface made as smooth as possible with the paddle, it should be further dressed with a body file, Fig. 50-32, and then sanded with a power sander. Painting is done in the usual manner.

Lead solder is also used to cover welds, Fig. 50-33. In such cases, the welded seam is first driven below the surface of the surrounding metal. This is done with a blunt edged dolly and a hammer or power tool. A groove a little wider than the weld, and about 3/16 in. deep will be produced. The groove is sanded, tinned and filled with solder. A body file should then be used to rough down the surface of the solder and a power sander used for final finishing.

Rain gutters and beading are difficult to straighten, and a lot of time can be saved by forming them with body solder. After tinning, the solder is applied in the usual manner and rough formed with the paddle while still soft. Files, scrapers and sanders are then used to finish form the gutter or beading to the desired shape.

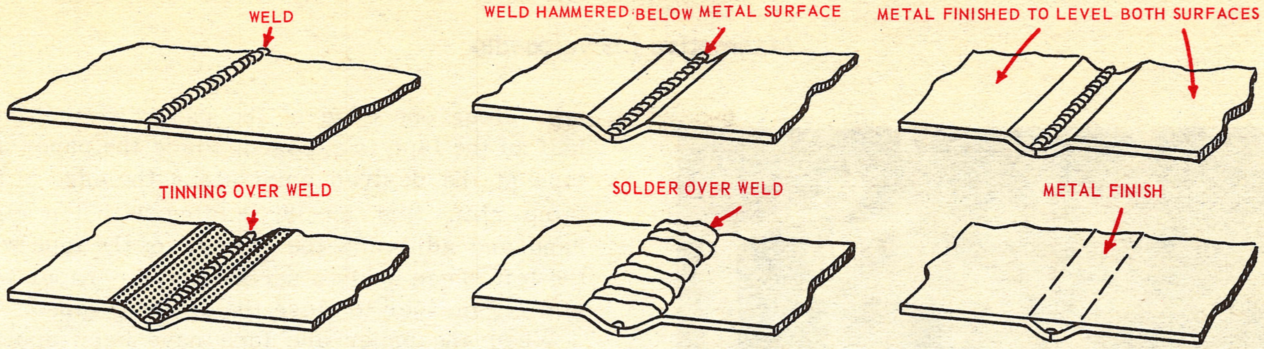
50-32. Smoothing the solder-covered surface with a body file.

REPLACING PANELS

In cases where body damage is extensive, instead of straightening the damaged area, time can be saved by installing a new panel or part such as a complete door or trunk lid. In the case of a damaged body panel, it becomes necessary to cut out the damaged area and weld in a section of a new panel. Replacement panels are available and either the entire panel is replaced or only a portion can be used depending on the size of the damaged area.

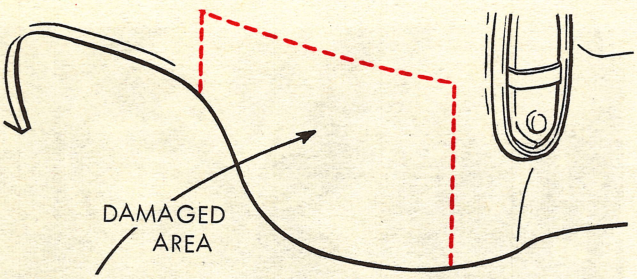
In replacing the panel, the procedure is as follows:

Rough out and shape the damaged area, making sure that the undamaged portion is in correct contour, and is not sprung out of alignment.


WELD
WELD HAMMERED BELOW METAL SURFACE
METAL FINISHED TO LEVEL BOTH SURFACES
TINNING OVER WELD
SOLDER OVER WELD
METAL FINISH

50-33. *Steps in covering welded joint with solder.*

Carefully measure the piece of metal to be replaced, Fig. 50-34. These measurements should be taken from the edge of the panel, the moulding or beading. This is important, as these points are to be transferred to the replacement panel. Scribe a line around the area to be cut from the service panel, and cut along the scribed line. The method of cutting will, of course, vary with the type of equipment available. Electric arc, gas or mechanical cutters can be used.



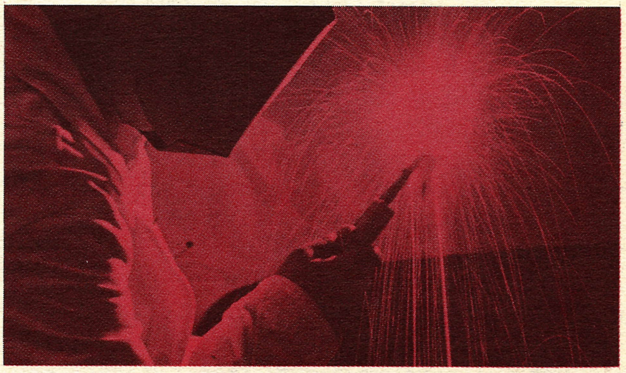
50-34. *Outline the damaged area of the fender as shown.*

The edges of this portion of new panel are carefully straightened, the new section is positioned over the damaged area and a line scribed around its outer edge. This line is now used as a guide in cutting out the damaged area, Fig. 50-35.

After straightening the cut edge of the fender on the car, fit the new section in position and hold it by means of C-Clamps, Fig. 50-36. Tack weld the section in place, starting the welds at the top center and work out to the sides and then down the sides. Then make a continuous weld, doing a length about six inches long at a time. To reduce distortion, the welds should be staggered.

With a grooved dolly, hammer the weld so it is about 1/16 in. below the surface of the surrounding panel, Fig. 50-33. This area around the weld is then sanded with a power sander or filed to produce the correct contour. Next fill the groove with hot or cold solder and then sand the surface to prepare it for painting.

If the damaged area to be replaced is at a pillar post or at a spot-welded seam, the seam can be split by driving a thin sharp chisel between the two pieces.

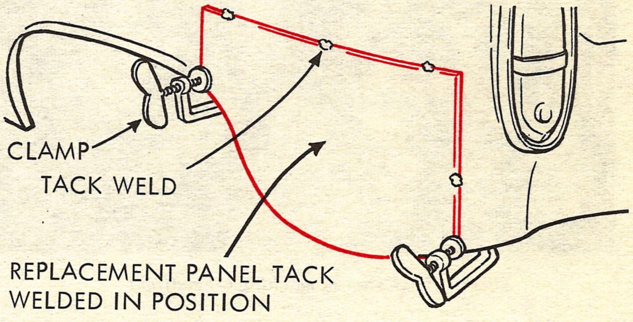


50-35. *Cutting damaged area from fender with electric torch.*

MASKING

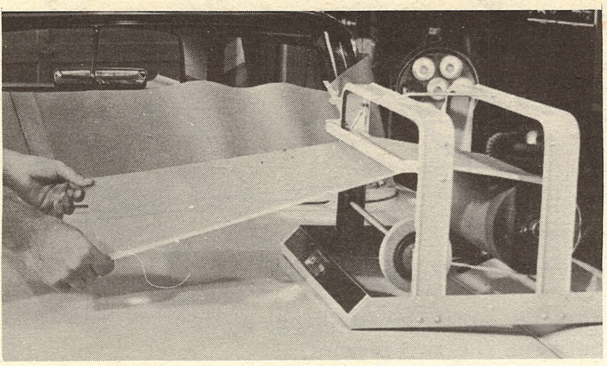
In order to protect surfaces and panels, while adjacent areas are being painted, the car is covered with paper which is secured in position with tape. The paper is called masking paper and the tape is known as masking tape.

Manufacturers of masking tape and paper have devoted much time and expense to improving their products and their research in this field has produced special tape and paper dispensers, Fig. 50-37, as well as shortcut methods of doing the actual masking.



50-36. *Secure the section of new fender in place with C-clamps and then weld in place.*

Good quality masking paper will not permit any paint to penetrate or seep through to the panel it is protecting. It should be of tough

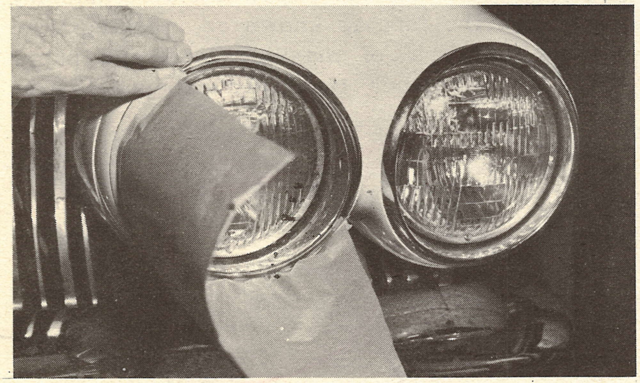


50-37. *Dispenser for masking paper and tape.*

texture, but flexible and at the same time there should be no possibility of it scratching the painted surface.

Tape, of course, must adhere easily to painted and unpainted surfaces, chrome and other materials and be of strong texture so that it will not tear readily as it is being applied. Tape must also retain its adhering qualities when it is drenched during wet sanding operations. Flexibility or stretch is another desirable characteristic of masking tape. This is important when applying the tape to the rounded corners of window frames, etc.

One of the new time saving methods automatically applies the tape along the edge of the masking paper so that half of the width of tape extends beyond the edge of the paper. The paper is then placed in the desired position on the car, and the exposed area of the tape when pressed against the panel or trim will hold the masking paper in place. This method is faster than the former method when the paper was held against the car and the tape applied to the paper and car at the same time.

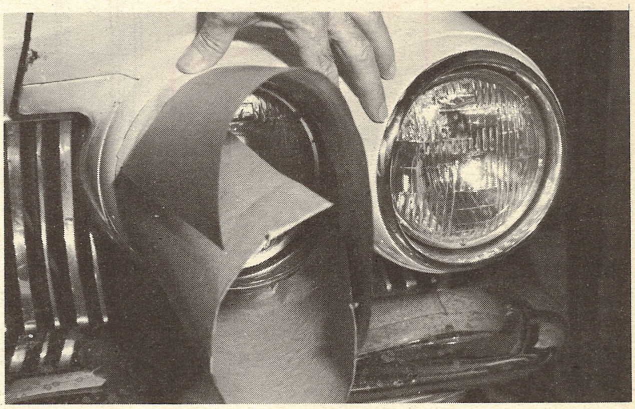


50-38. *First step in masking a headlight.*

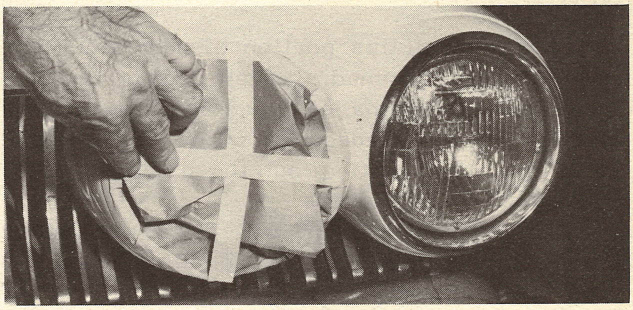
To mask a headlight use 6 in. wide paper and cut a piece that will go approximately three-fourths the distance around the light. Place the tape along one edge of the paper, so that one-half of the tape is exposed. Place the paper and tape at the desired point along the edge of the lamp rim, Fig. 50-38, leading with the right hand and adjusting the position of the tape with the left. Then apply a second piece of paper in a similar manner to close the exposed gap.

When the paper and tape have been applied all around the lamp rim, the masking paper will be cone shaped, Fig. 50-39. Twist and fold the cone against the front of the lamp.

Take two short pieces of tape and place them so that the paper will be held flat against the lamp, Fig. 50-40.



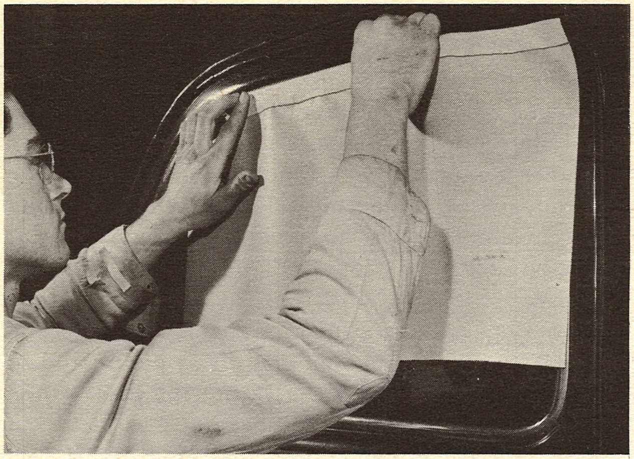
50-39. *Placing second piece of masking paper on rim of headlight.*



50-40. *The cone-shaped masking paper covering the headlight is folded back and then taped down with strips of masking tape.*

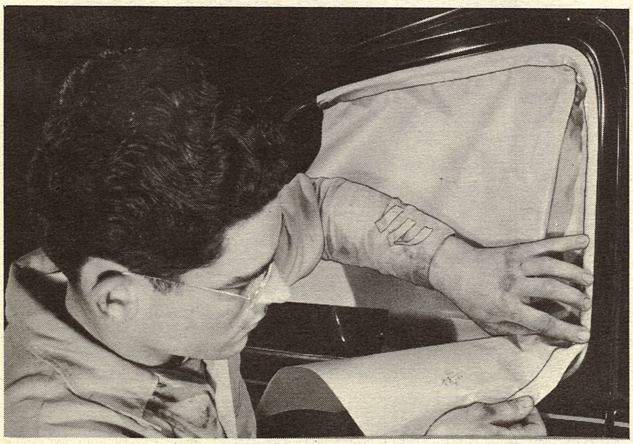
There are many different methods of masking a window. One method is shown in Figs. 50-41, 42 and 43. The first piece is applied along the upper edge. The second, along the right side and portion of the bottom edge, while the third covers the wind deflector and remaining portion of the lower edge. Use short pieces of tape to hold the folds down. Be sure that the lower sheets are underneath the upper sheet. This will prevent water from wet sanding running underneath the paper.

When you have to apply a masking apron

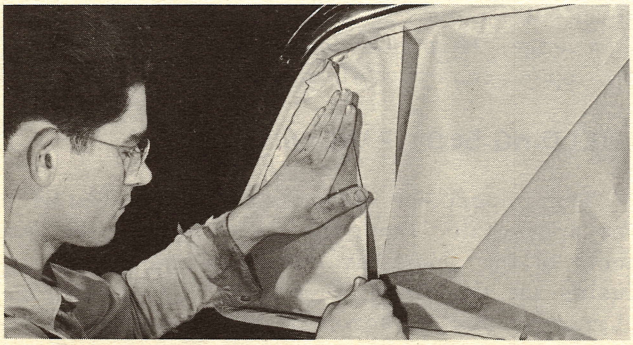


50-41. *When masking a window, the first piece of paper is placed along the upper edge.*

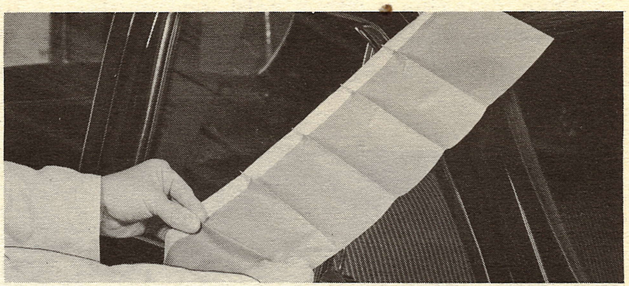
around an inside curved surface, first pleat the apron, Fig. 50-44. This will make it easier to follow the curved contour, and will prevent the apron from bunching and wrinkling. Here's how it is done: (1) Cut a piece of masking paper the desired length, (2) Make a pleat about 1/4 in. deep by crimping both edges. The pleat should extend the full width of the apron. (3) Continue pleating the full length of the apron, making a pleat every two to four inches, (4) Apply the apron to the surface. Then, after pleated apron is securely in place, fold the untaped edge so that it will catch the over spray.



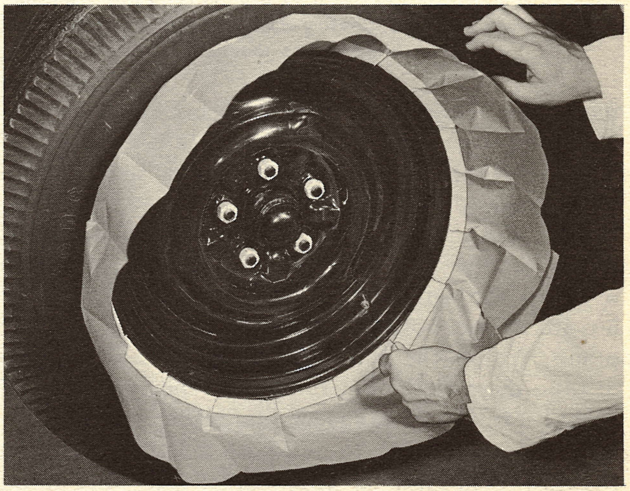
50-42. *The next step is to place masking paper along the right side of the window.*



50-43. *Use a third piece of masking paper to cover the forward portion of the window, with short pieces of tape to hold the edges down.*

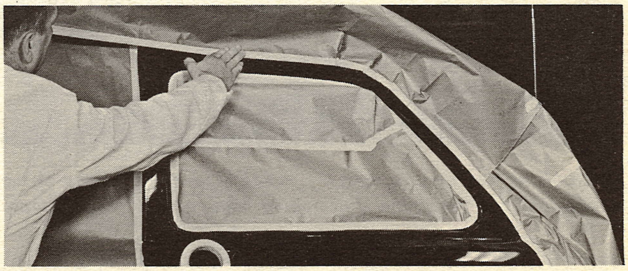


50-44. *When applying masking paper to a curved edge, the first step is to pleat the paper.*



50-45. *Applying masking paper, which has been pleated, to a wheel.*

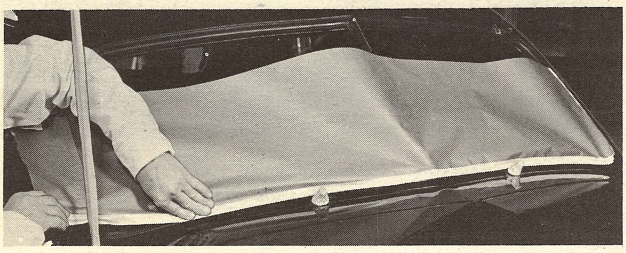
This "pleating" method can be used to good advantage on wheels, Fig. 50-45, and also on the curved edge of doors as shown in Fig. 50-46.



50-46. *Applying masking paper to the curved edge of a door. Note the pleats in the paper.*

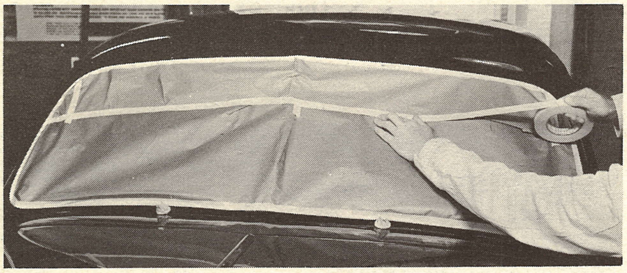
When using this method to mask a wheel, it saves the time of removing the wheel and tire. The procedure is to simply apply a pleated six inch wide mask around the entire circumference of the rim, securing the tape to the surface of the tire. Then, after removing the hub cap, the wheel and hub can be sprayed.

When masking a windshield, one method is to use 3/4 in. tape on 12 in. wide masking paper for the initial step, Fig. 50-47. Next, lay the paper on the windshield from bottom to top---securing the tape to the window's bottom edge. The overlapping ends of the mask should then be curved up the two side edges. After the 12 in. mask is in place, lay a 6 in. mask along the windshield's top edge---allowing the paper to overlap the surface of the first covering, Fig. 50-48. When both the 6 and 12 in. masks are in place, finish the job by applying a 3/4 in. strip of tape over the seam formed by the overhanging mask. For very large windshields, however, it may be necessary to use both a 12 in. mask on the lower portion of the window, as well as on the top.



50-47. One method of masking a windshield is to use ¾ in. tape on 12 in. masking paper, covering the lower section of the windshield first as shown.

Before masking a front door, first mask off all chrome fittings and moldings. Secondly, apply a 12 in. wide length of masking paper over the lower portion of the window, and a 6 in. wide mask over the upper portion. For the third step, apply a 12 in. wide mask from the door's rear edge back over the rear window and side panel area. A similar 6 in. wide mask is applied from the front fender to the rear fender along the door's bottom edge. Finish the job by running a partially pleated 12 in. mask along the door's forward and top edges to protect the fender and roof from overspray while painting. (Pleating the paper permits it to conform to the door's curved edges.)

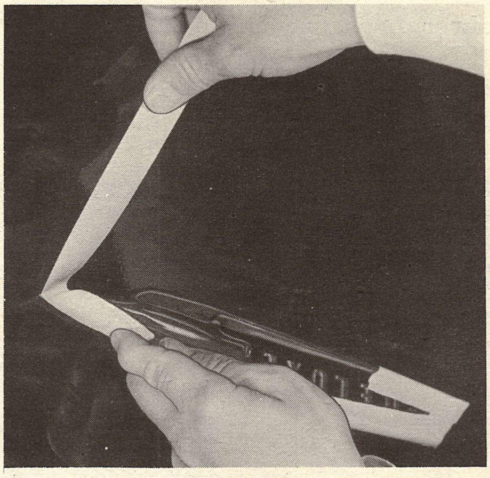


50-48. The next step is to apply masking paper to the top of the windshield and cover the overlapping edge with a strip of tape.

Some manufacturers emphasize that masking tape should never be pulled or stretched during application; that the proper method is to lay it down easily as it comes from the roll. In this way, the possibility of it pulling back during the painting operation is eliminated. By not stretching the tape's crepe backing it is permitted to expand and contract without pulling away when the solvents are applied.

For inside curves, narrow mouldings and tabbing, 1/4 in. or 1/2 in. width tapes are usually used. For wider mouldings 3/4 in. and 1 in. widths are more satisfactory.

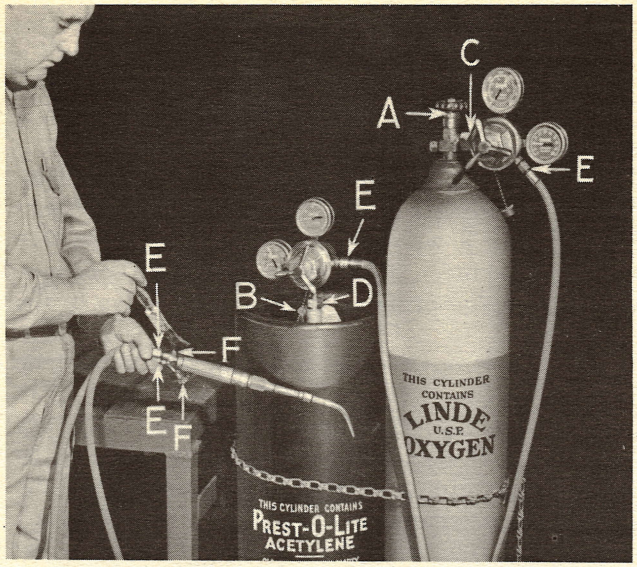
When masking fender emblems, Fig. 50-49, 3/4 in. tape will do an excellent job. First apply the tape along the edges of the emblem to form a sharp separation line. At sharp outside curves, lay the tape over the sharpest point of the curve and draw the loose ends back along the edge of the emblem. After all the edges have been masked, finish by filling the open areas with short strips.



50-49. Masking emblems can be quickly done with wide tape as shown.

WELDING BODY PANELS

The importance of welding in a shop can best be appreciated from the fact that over 85 per cent of the shops have such equipment. Skill in using the equipment is not difficult to develop. Practice and a thorough understanding of the adjustment of the flame and the selection of the correct tips for the different types of work are the main requisites in the case of gas welding,


C
A
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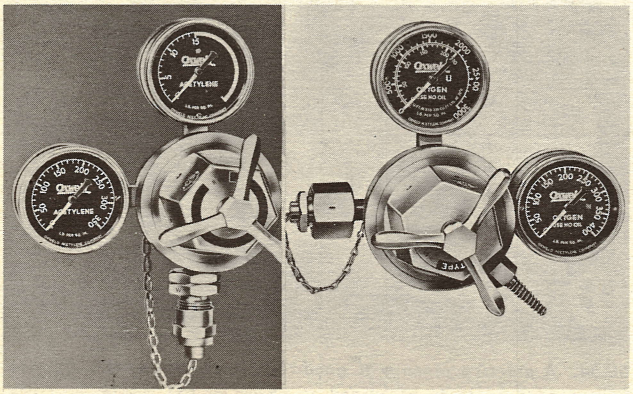
THIS CYLINDER CONTAINS LINDE U.S.P. OXYGEN
THIS CYLINDER CONTAINS PREST-O-LITE ACETYLENE

50-50. Oxygen and acetylene cylinder should be mounted in a truck or chained to a post or work bench.

and the correct current when welding or cutting with electricity.

Before starting any gas welding or cutting job, it is important that the oxygen and acetylene cylinders be either chained to a post or placed in a special cylinder truck, Fig. 50-50. This prevents them from being tipped over. Before attaching the regulators, Fig. 50-51, to the cylinders, each valve should be opened slightly to blow any dirt from the valve seat. To avoid danger of fire, be sure there is no flame or sparks close to the acetylene cylinder and always be certain that fire extinguishers are nearby. Remember that the acetylene connections have left hand threads. Acetylene connections can also be recognized, as they are painted red, while oxygen connections are green.

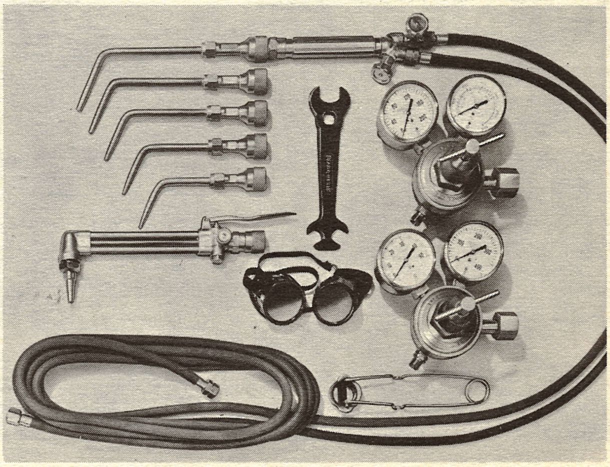
After installing the oxygen regulator, open the regulator hand wheel. The lower gauge will register the pressure in the tank. After attaching the acetylene regulator, open the acetylene valve about 1 1/2 turns.



50-51. An acetylene regulator is shown at the left and an oxygen regulator at the right.

After connecting the welding hoses to their respective regulators, the welding head (tip) and blow pipe, Fig. 50-52, is connected to the other end of the hoses. The size tip selected will depend on the type of welding or cutting that is to be done. The size designation varies with different manufacturers. However, when welding body sheet metal, the smallest tip is usually used. Similarly, if body sheet metal is to be cut, a small tip is preferred. Larger size tips are needed if heavy sections, such as frames, are to be welded or cut, and still larger tips are used when heating axles preparatory to straightening, etc.

Different pressures are needed for welding and cutting different thicknesses of metal. For welding sheet metal, the acetylene pressure should be 5 p.s.i., while the oxygen pressure should be 10 p.s.i. For cutting sheet metal, the pressure of the oxygen should be 10-15 p.s.i., and acetylene 3-5 p.s.i.



50-52. Welding and cutting torch, together with gauges, wrench and igniter. Note assorted tips for welding.

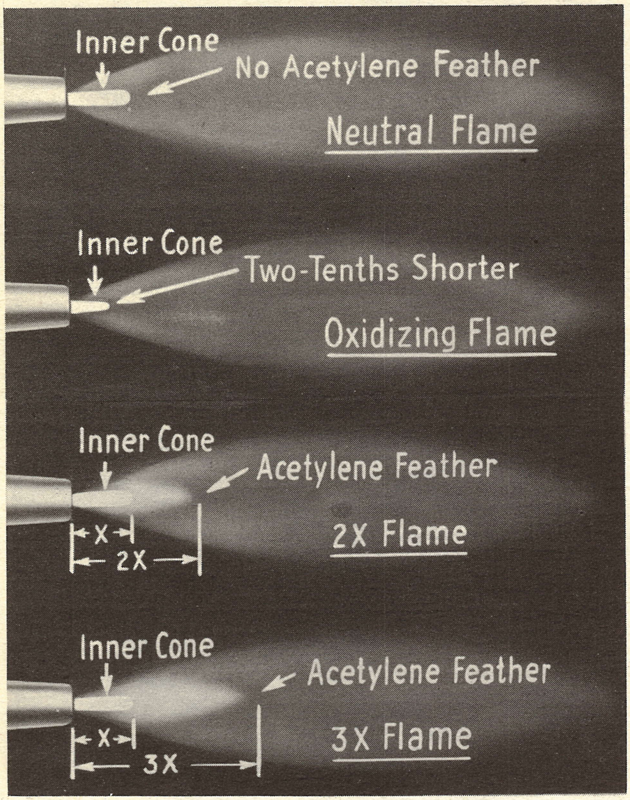
To light the flame, first open the oxygen valve 1/4 turn. Then open the acetylene valve one full turn and light the gas at the tip with a friction-type lighter. Never use matches. When lighting the gas, have the tip of the torch turned down and away from any person standing nearby.

Adjusting the flame is accomplished by opening the oxygen valve slowly. The flame will change from a yellow acetylene flame to a blue flame which is called a reducing flame. Starting with an excess acetylene flame, a neutral flame is obtained by closing the acetylene valve until the acetylene "feather" at the inner cone of the flame disappears, Fig. 50-53.

To obtain an oxidizing flame, either increase the oxygen or decrease the acetylene until the inner cone of the flame is about 2/10 shorter.

If the flame is yellow or backfires, readjust the acetylene to 10 p.s.i., and open the torch needle valve more. If this does not correct the condition, the torch probably requires cleaning.

To weld sheet metal, a neutral flame should be used, and skill can be attained by practicing on strips of sheet steel. At first do not attempt to weld two pieces of sheet steel together, but move the flame across the surface of the sheet metal, carrying the "puddle" along the surface, Fig. 50-54. Do not use any welding rod. The purpose of this exercise is to obtain skill in carrying a puddle across the surface of the sheet. The blow pipe or torch should be held so that the flame points in the same direction that the weld will be made, and at an angle of about 45 deg. The inner cone of the flame should be about 1/8 in. away from the surface of the sheet. Hold the torch in this position until a pool of molten metal about 3/16 in. to 1/4 in. in diameter is formed. Then move the torch slowly to move the puddle in the desired direction to obtain an even ripple effect. To do this, the torch should be swung from side to side in a small arc. If the torch is moved too slowly, holes may be burned through the sheet metal. If the torch is moved too quickly, the desired degree of melting and overlapping of the puddles will not be obtained.



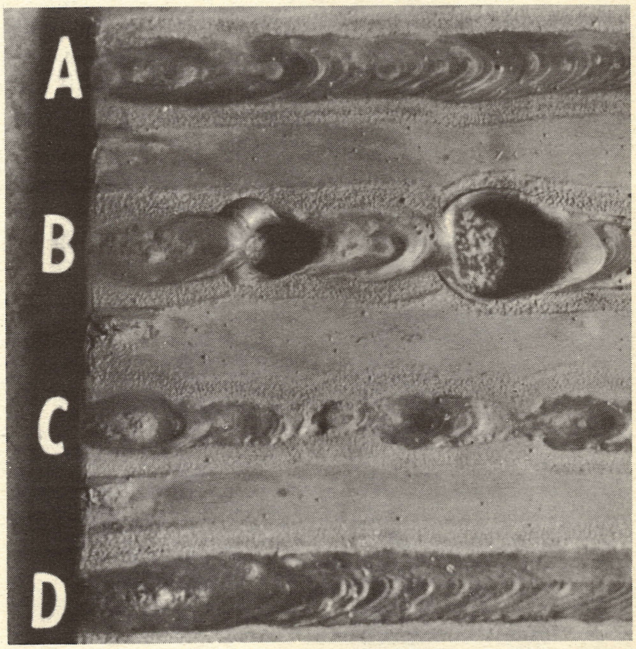
50-53. Illustrating the method for indicating the amount of excess acetylene to be used. After the flame had been adjusted to neutral, the blowpipe acetylene valve should be opened, or the oxygen valve closed until the desired acetylene feather is obtained.

After the desired skill is attained without using a welding rod, repeat the preceding exercise, using a welding rod, Fig. 50-55. In this case the addition of the welding rod will produce a slight ridge of metal above the surface of the sheet.

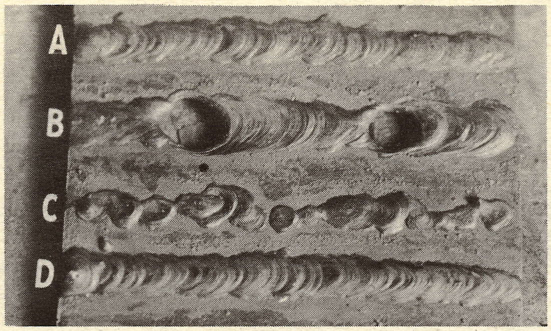
The position of the welding rod should be similar to the welding torch, except that it is held in the left hand and at an angle of slightly more than 45 deg. The spot on the sheet and the tip of the welding rod should be brought to the melting temperature at the same time. It will be found that the best position for the end of the welding rod is just inside the outer end of the flame while the flame is being concentrated on the spot at the start of the weld.

After having practiced the use of the welding rod, place the edges of two pieces of sheet iron 1/16 in. apart and weld them together. In this case it is important that the welding action penetrate completely through to the underside of the sheet so that the weld will have sufficient strength.

During the welding action the welding puddle must be controlled so it will not fall through the gap. However, the metal added from the rod



50-54. A practice piece with good results at (A) and (D). Excess heat caused holes to be burned as shown at (B), while too little heat was used at (C). No welding rod was used when making this practice piece. (Linde Air Products Co.)



50-55. *Example of good and poor welds. Those at (A) and (D) are satisfactory, while the weld at (B) shows the effects of too much heat. Insufficient heat, little fusion and improper melting of the welding rod produced the weld shown at (C). (Linde Air Products Co.)*

must be thoroughly fused with the base metal on both sides of the joint for the entire thickness of the sheet.

After sufficient skill has been attained on welding small sheets of metal together, work on an actual fender or body panel can be attempted.

BODY PANEL CUTTING METHODS

With the car body construction as used today, many shops have adopted the policy of replacing sections of panels rather than attempting any straightening operations. In cases of severe damage, such procedure saves a great deal of time and not only enables the shop to turn out more jobs per day, thereby increasing profits, but also often results in lower prices to the customer. Replacement panels are available from car dealers and independent parts jobbers.

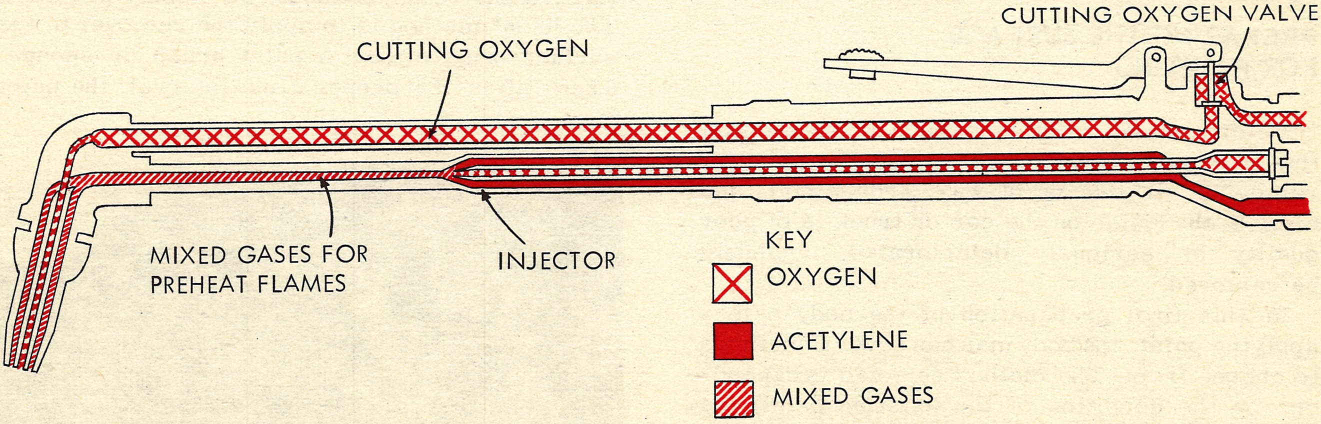
Cutting out such panels is relatively simple with the equipment that is available. There are three basic types of such equipment, the oxy-acetylene cutting torch, Figs. 50-56, 57 and 58, the electric torch and various types of power driven cutters. All are good, and all have their adherents among body shops.

To cut sheet metal with oxy-acetylene a special torch, Fig. 50-56, is needed which differs materially from the one used for welding. A cutting torch provides a stream of pure oxygen which does the actual cutting after the starting point of the cut has been heated to a red temperature by small oxy-acetylene flames. In the cutting torch, the oxy-acetylene flames are produced at a series of openings in the tip. These openings surround the central opening or jet from which the oxygen passes. Details of construction vary with different manufacturers.

Cutting is accomplished when the sheet metal is heated red hot and exposed to the oxygen. An intense reaction then takes place, and so much heat is then liberated that not only is the oxide that is formed melted, but some of the unoxidized steel or iron is heated sufficiently so that it, too, is melted. So that the direction of the cut can be changed, cutting nozzles are made with a ring of openings, usually four or more, which surround the oxygen orifice. In this way, several smaller flames of oxy-acetylene are supplied so that the direction of the cut can be changed.

The cutting torch has two valves to regulate the quantities of oxygen and acetylene that are mixed, for the pre-heat flame, and a third valve usually operated by a lever, controls the stream of oxygen.

When using a cutting torch, the same safety precautions specified for welding should be followed. Fire extinguishers should be readily available, and it must be remembered that it is unsafe to feed oxygen into a confined space, as it will cause oil, wood, clothing, or sound deadening material if ignited, to burn with great



50-56. *Sectional view of oxy-acetylene cutting torch.*

intensity.

When cutting out a body panel, the line along which the cut is to be made should first be marked with chalk. It is important that allowance be made for the width of the metal that will be melted. The chalk mark should, therefore, be made approximately 1/2 in. from the desired line. Any upholstery or other material should be removed from the opposite side of the panel. Most mechanics use both hands when cutting metal with a torch, one to control the flow of oxygen and the other to steady the torch. The torch nozzle is held perpendicular to the surface of the work and kept in the same spot until the metal is bright red. The oxygen valve is then opened and as soon as the flame starts cutting, there will be a shower of sparks from the opposite side of the metal. The torch is then moved slowly, but steadily, in the desired directions.

If the torch is moved too slowly, the heat from the pre-heating flames will tend to melt the edges of the cut and produce a ragged appearance. If it is moved too fast, the cutting jet will fail to go through the metal. Should this occur, close the oxygen valve and reheat the point where the cut stopped, and then reopen the oxygen valve to start the cut again.

Cutting is also done with an electric arc, Fig. 50-57. While any electric arc welder can be used for cutting, the use of large high-capacity units results in too wide a cut and considerable wastage of metal. The smaller, low-amperage units are, therefore, preferred for cutting and also welding body sheet metal.

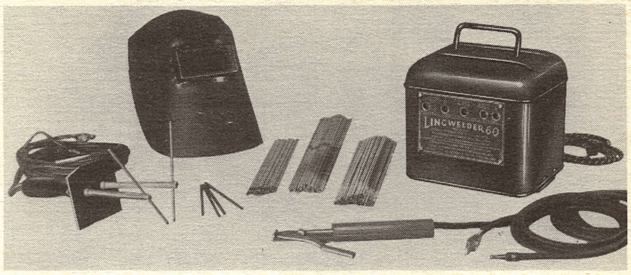
Hand shears can also be used, but body men prefer special cutters which are driven by electric or pneumatic drills, Fig. 50-58. Such cutters can cut curves with radii as small as 1 in. and are used to cut sheet metal up to .040 in. They have the advantage of not bending or stretching the metal and no burrs are produced.

PREPARING THE SURFACE FOR PAINTING

Before actual painting begins, it is essential that the surface be prepared for the paint by removing all traces of wax, grease, oil, and dirt. If the paint on the car or truck is of poor quality or seriously deteriorated, it should be removed.

In this final preparation of the body before applying paint, the body man has several methods to choose from. The method selected is dependent on the condition of the existing paint, the equipment available and quality of the finished job desired.

If the paint on the car is in good condition; that is, it has good adherence and is without surface defects, most shops prefer to go over the surface with a disk sander. An open coated disk of No. 16 to 24 grit is used. The disk is held at a slight angle to the surface and worked forward and backward. This will remove most of the old finish down to the metal. This is then followed with a No. 50 close coated disk to remove scratches. If the paint is being removed from only a portion of the panel, the sanded area should taper back into the old paint to produce a feather edge, Fig. 50-23. This is then followed with a 150 grit paper in a block sander, and the final feather edge is obtained by water sanding with wet or dry paper of 280 or 320 grit. Some manufacturers of abrasive paper will advise different grits with variations of the above procedure. Body mechanics should then follow the instructions of the manufacturer.

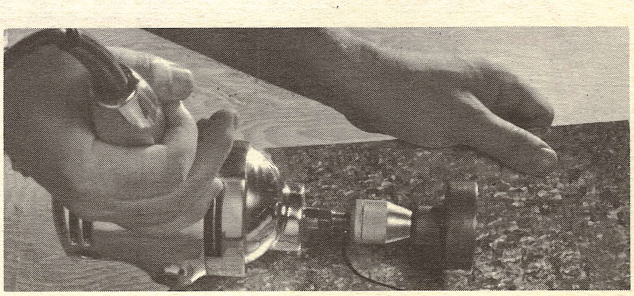


50-57. Electric equipment for welding and cutting.

The foregoing is a popular method for preparing the surface for touching-up and refinishing individual panels and is also used for the entire vehicle if the original paint is in poor condition.

For removing paint from the entire vehicle, many shops prefer sand blasting, hot caustic strippers or paint removers.

When using paint removers, the manufacturer's instructions should be closely followed. The usual method is to apply the remover to the surface with either a paint brush or sponge. Then, after the proper time interval, the paint



50-58. One type of mechanical cutter for use on body panels.

is scraped from the surface with a putty knife or in some instances, it can be flushed from the surface with a strong stream of water or steam. Because of fumes, paint remover should only be used in well ventilated rooms.

The use of sand blasting for removing paint is favored by many shops. In metropolitan areas there are specialists who limit their work to removing paint by this method and who are patronized by car dealers, independent repair shops and paint shops. Among the advantages claimed for the sand blast method are: Speed, low cost and the surface resulting in good paint adherence.

After removing paint, the surface should be further cleaned with special cleaners to remove any rust, wax, or oil film. This is necessary to obtain good paint adherence.

Primer coats should be applied as soon as possible after the paint is removed. This is particularly important when the surface has been sand blasted, because the metal surface is practically in the raw state and will quickly start rusting.

Steam cleaning of a chassis and engine forms part of any good paint job, and in itself is a profitable shop operation.

AIR REQUIREMENTS FOR PAINTING

Too often when a shop owner decides to start a paint department he simply runs an air line to the compressor, connects a spray gun and thinks he is ready for business. True, the set-up will spray paint, but it will also spray a lot of oil, dust and condensed moisture from the compressor. In addition, because of pressure variation the resulting spray pattern will vary

AIR OPERATED EQUIPMENT	ESTIMATED AVERAGE C.F.M. Air Consumption	A No. of Units of Each Type	B C.F.M. Per Unit	C Total C.F.M.	D Total C.F.M. Times Factor 100	E Total C.F.M. Times Factor 300	F Total C.F.M. Times Factor 500
Air filter cleaner							
Dusting gun							
Car lift							
Drill							
Engine cleaner							
Fender hammer							
Garage door opener							
Grease gun							
Spray gun (touch-up)							
Spray gun (production)							
Sander							
Spark plug cleaner							
Tire inflator							
Tire changer							
Undercoat gun							
Vacuum cleaner							
Wrench							
					Total D	Total E	Total F

1. Add D, E, F together. Place a decimal point before the last three figures. This will give the minimum C.F.M. required of the compressor.
2. Add on 1/4 of the above as a safety factor.
3. Add the above two for recommended minimum rating of the compressor required.

Transfer total here → ________

Transfer above total here ____ → ________

50-59. *Estimating compressed air requirements of the shop.*

considerably. The net result is poor paint jobs.

Among the first steps in setting up a paint department, is to make sure there is adequate air to handle the spray guns and other air operated equipment that is connected to the compressor. In addition, it must be ascertained that the shop air compressor is in good mechanical condition and is delivering its rated capacity. In this connection many shops find it advisable to install a separate compressor for paint work. This not only avoids overloading the shop air compressor, but also the additional equipment can be cut into the shop line in case of emergency.

To estimate the compressed air requirements of the shop and the load on the compressor, it is necessary to know the amount of air used by the pneumatic equipment in the shop. The method of calculating the total requirements is given in Fig. 50-59.

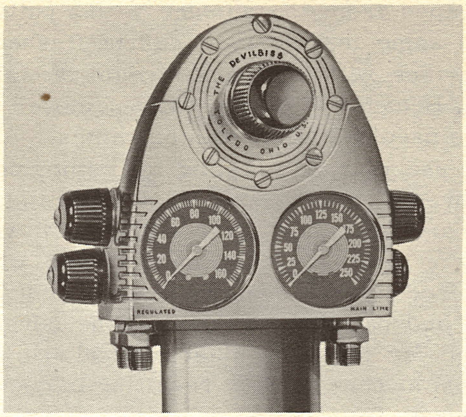
Referring to Fig. 50-59, you will note columns designated A, B, C, D, E and F. Column D is for equipment in average intermittent repair shop use; column E is for use where specialized departments are maintained, as, for example, a paint department where several different air operated tools may be used by possibly only one man; column F is for the use of large shops where there may be several hammers, paint guns or other equipment requiring a relatively steady supply of air.

In using this form you should obtain the actual consumption of the tools in your shop. When column C is completely filled out, then multiply each figure in the column by the factor given in column D, E or F, whichever applies to your shop conditions, and place the answer in that column.

	AIR PRESSURE DROP AT SPRAY GUN				
Size of Air Hose	5 ft. length	10 ft. length	15 ft. length	20 ft. length	25 ft. length
¼ in.					
at 40 lbs. pres.	6.0 lbs.	8.0 lbs.	9.5 lbs.	11.0 lbs.	12.7 lbs.
at 50 lbs. pres.	7.5 lbs.	10.0 lbs.	12.0 lbs.	14.0 lbs.	16.0 lbs.
at 60 lbs. pres.	9.0 lbs.	12.5 lbs.	14.5 lbs.	16.7 lbs.	19.0 lbs.
5/16 in.					
at 40 lbs. pres.	2.2 lbs.	2.7 lbs.	3.2 lbs.	3.5 lbs.	4.0 lbs.
at 50 lbs. pres.	3.0 lbs.	3.5 lbs.	4.0 lbs.	4.5 lbs.	5.0 lbs.
at 60 lbs. pres.	3.7 lbs.	4.5 lbs.	5.0 lbs.	5.5 lbs.	6.0 lbs.

50-60. *Air pressure drop at spray gun.*

When these figures have all been totaled up, as indicated on the chart, you will notice that you have the minimum c.f.m. required of the compressor. As it is desirable to have a safe working margin for unusually busy periods and to handle future additional tools or equipment, it is recommended that 25 per cent be added to the total.



50-61. *Air transformer with regulator provides clean air and regulates air pressure. (De Vilbiss)*

Simply totaling the c.f.m. demands of the various pieces of equipment in the shop does not furnish the capacity of the air compressor required, the reason being that some tools and equipment are used for only a short period and at irregular intervals, while others are used almost constantly. To obtain the capacity of the compressor required to operate the shop's equipment simply follow the instructions in the table.

To get the best performance and long life from any air compressor, it must be serviced and inspected at regular intervals. A compressor and its separator or transformer used for paint spraying require more special care if clean air is to be supplied.

The manufacturers' service instructions should be carefully followed. If these are not available, the oil in the compressor should be changed every 60 to 90 days. The air filter should be cleaned each month, and the air tank or receiver should be drained every morning. Another daily job is draining the air transformer. In fact, in extremely humid weather this should be done several times each day.

If the equipment is provided with a separate receiver with a pop valve, it should be checked occasionally to make sure that it is operating correctly. Otherwise, check the pressure gauges and switches, noting the time required to cut-in and cut-out. This time interval compared to the specified time will serve as a warning for many air supply system troubles.

Of course all lines should be checked for leaks. When installing a new system it is important to select pipe of sufficient size to carry the necessary amount of air. Also when installing the piping it should always drain back to the receiver, rather than forward to the air hose.

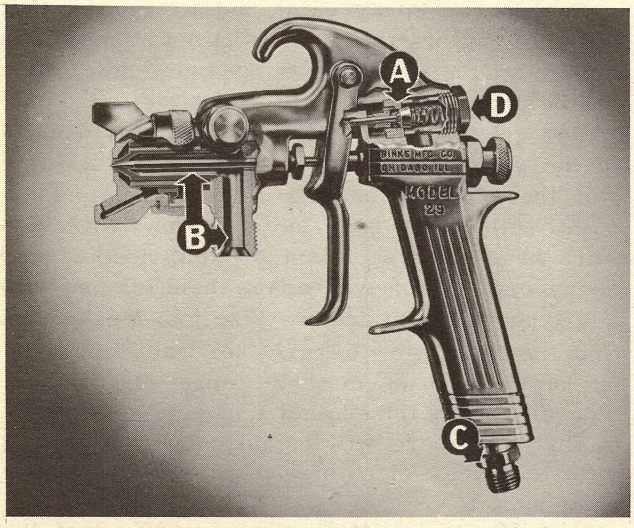
Air hose must also be of adequate size to keep air pressure drop at a minimum, Fig. 50-60. Common sizes of spray gun air hose are 1/4 in., 5/16 in., and 3/8 in. Naturally, the smaller the diameter, the greater loss in pressure. The 3/8 in. diameter hose is the preferred size.

CARE OF A SPRAY GUN

There are a lot of factors which determine the quality of a paint job, and one of the most important is the condition of the spray gun and the way in which it is used.

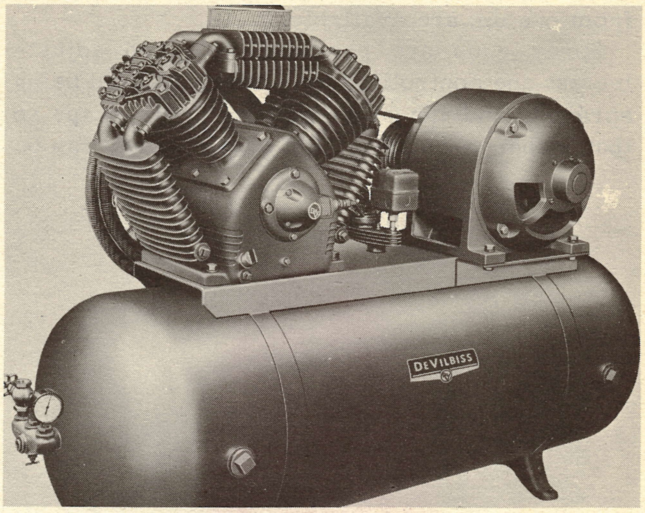
It is impossible to do a good job of spray painting with a gun that has not been cleaned or is otherwise defective. Furthermore, the compressed air used for spraying must be free of moisture, oil, and dirt, and pressures must be accurately regulated. In other words, the compressor must be equipped with an extractor or transformer, Fig. 50-61, which not only regulates the pressure but also provides clean, filtered air for painting.

The manufacturer's instructions should be carefully followed when taking care of a spray gun. In general, such instructions emphasize thorough cleaning each time the gun is used, and lubricating of the bearing surfaces and packing at regular intervals.



50-62. Sectional view of a Binks paint spray gun. Note the cartridge type air valve (A). Passage for paint, lacquer or enamel, (B). Air entrance at (C) or if desired at (D).

Thinner is used to clean the gun, but it should never be immersed in the solution, as it will destroy the lubricant in the packing. A knife, wire or other metal implement should never be used to clean out the air passages. Caustic and acid solutions should never be used for cleaning, as they will corrode the aluminum alloy of which portions of the gun are usually made.



50-63. Air compressor designed specifically for spray painting.

As soon as the spraying is completed, the gun and cup should be cleaned immediately. The first step in cleaning a gun is to empty all the remaining lacquer or enamel from the cup. Then rinse the cup thoroughly with some thinner and then put a small quantity of thinner in the cup and spray through the gun in the usual manner. This will clean all the passages in the gun. Then dry the parts with air and the gun and cup will be ready for the next job.

The air valve stem should be lubricated daily with a few drops of light oil, and all packing should be kept soft and pliant by occasional oiling.

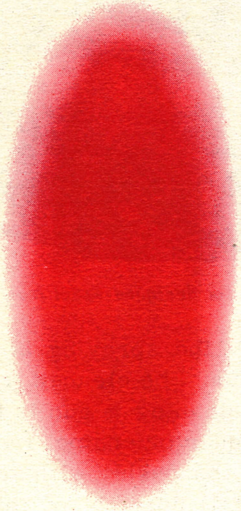
As pointed out before, the compressed air used for spray painting must be clean and free from oil or moisture. The air compressor must, therefore, be provided with an air transformer or oil and water extractor, as they are also called. Such units are designed to not only trap oil and water vapor and prevent them from reaching the gun, but also supply air at specified pressures suitable for different types of spray painting.

Transformers or extractors, Fig. 50-61, are available in different sizes so that one or more spray guns can be operated from a single unit. For large departments, pressure feed paint tanks are available. These are designed for conveyance of large quantities of finishing material to the spray guns, under constant and accurate control.

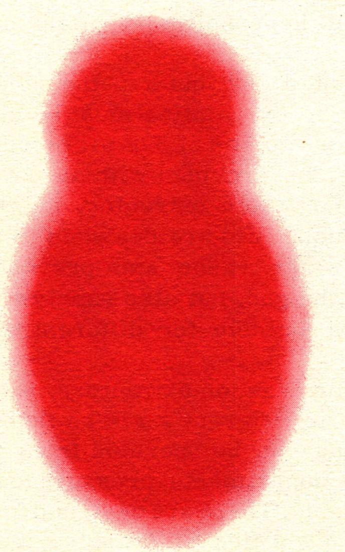
When setting up a paint spray department, it is important that sufficient air be available.

Many shops, therefore, find it advisable to use a separate compressor, Fig. 50-63, for such work. The size required will depend on the type and quantity of paint spray guns, and the refinishing material to be sprayed. Compressor units capable of handling any number of guns, from one up, are available.

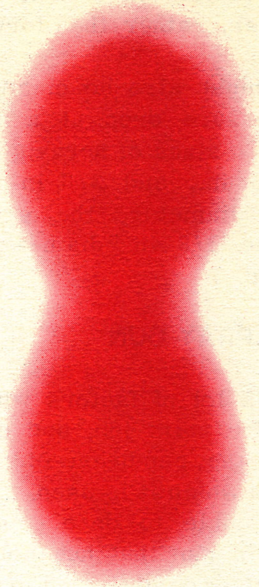
Spray guns are provided with two adjustments: one controlling the amount of fluid being sprayed, and the other governing its shape so that either a round or fan shaped spray can be obtained. The various patterns obtained from a spray gun are shown in Figs. 50-64 to 68 incl.



50-64. A correctly adjusted and clean spray gun, held at the correct distance from the work, should give a symmetrical pattern as shown.



50-65. Insufficient atomizing pressure will give a pattern heavy in the center or heavy at one end and light at the other.



50-66. If the spray pattern is light in the center and heavy at each end it indicates that the atomizing air pressure is too high. This can be corrected by increasing the width of the spray pattern or reducing the fluid pressure.

TIPS ON SPRAYING

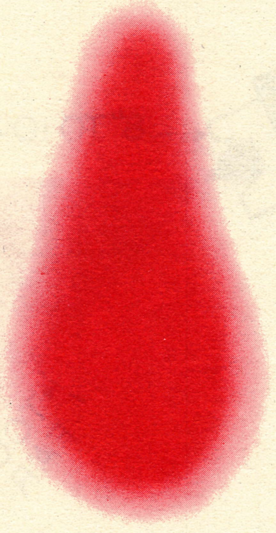
Anyone can spray paint, but to do a job that does not sag or ripple, and will dry smooth with maximum lustre, takes some know-how which can be acquired with a little practice.

The gun used for refinishing cars is usually of the syphon cup gun type, Fig. 50-69. On this gun the trigger controls both the air and the paint. All spray guns suitable for first-class work have an assortment of tips, needles and spray cups which will adapt them for use with any type material and any size job. Most shops find it advisable to have several guns, one for each type of material sprayed: primer, lacquer, synthetic enamel and acrylic enamel. In that way there will be no danger of mixing different types of paints which results in poor paint jobs. .

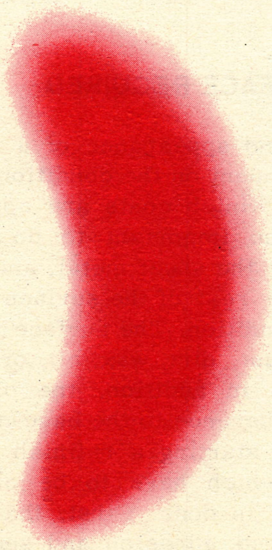
One of the "musts" in spraying is that the paint be at the correct viscosity. This can be best determined by following the instructions on the paint can. Too many painters determine the viscosity by the rate at which the paint runs from the stirring rod. This can lead to plenty of trouble, as only a slight change in viscosity can spoil an otherwise good job. The reason for this is that the amount of thinner not only determines the thickness of the coat, but also influences the evaporation rate between the time the material leaves the gun and the time it arrives at the body panel.

High viscosities usually result in sag and orange peel, while low viscosity produces improper flow-out and waste of thinner. It is, therefore, important to measure the proportions of thinner and lacquer or enamel accurately in a graduated measuring cup.

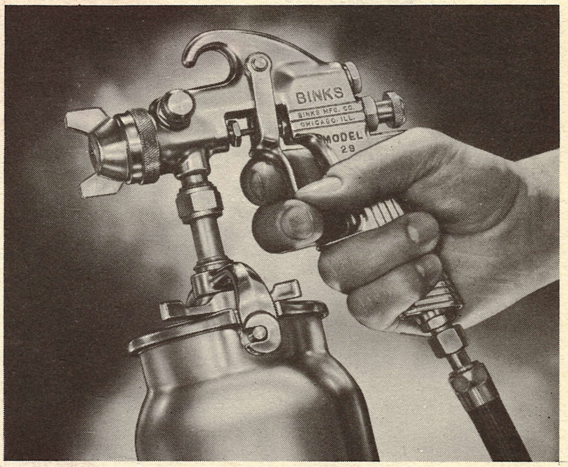
The temperature at which the spraying is done is also an important factor in turning out a good job. This applies not only to the temperature of the shop, but the temperature of the car or truck as well. Shop temperatures should be maintained at 70 deg. F. and the vehicle should be brought into the shop well in advance of spraying time so that it is the same temperature as the shop. Spraying lacquer on a surface that is too cold or too hot from being in the sun will upset the flowing time of the material and will cause orange peel and poor adherence to the surface.



50-67. *Dried fluid around the outside of the fluid nozzle tip, restricting the atomizing air will cause the pattern to be heavy and wider at either top or bottom.*



50-68. *A crescent-shaped pattern is caused by a wing port being clogged by dry material.*

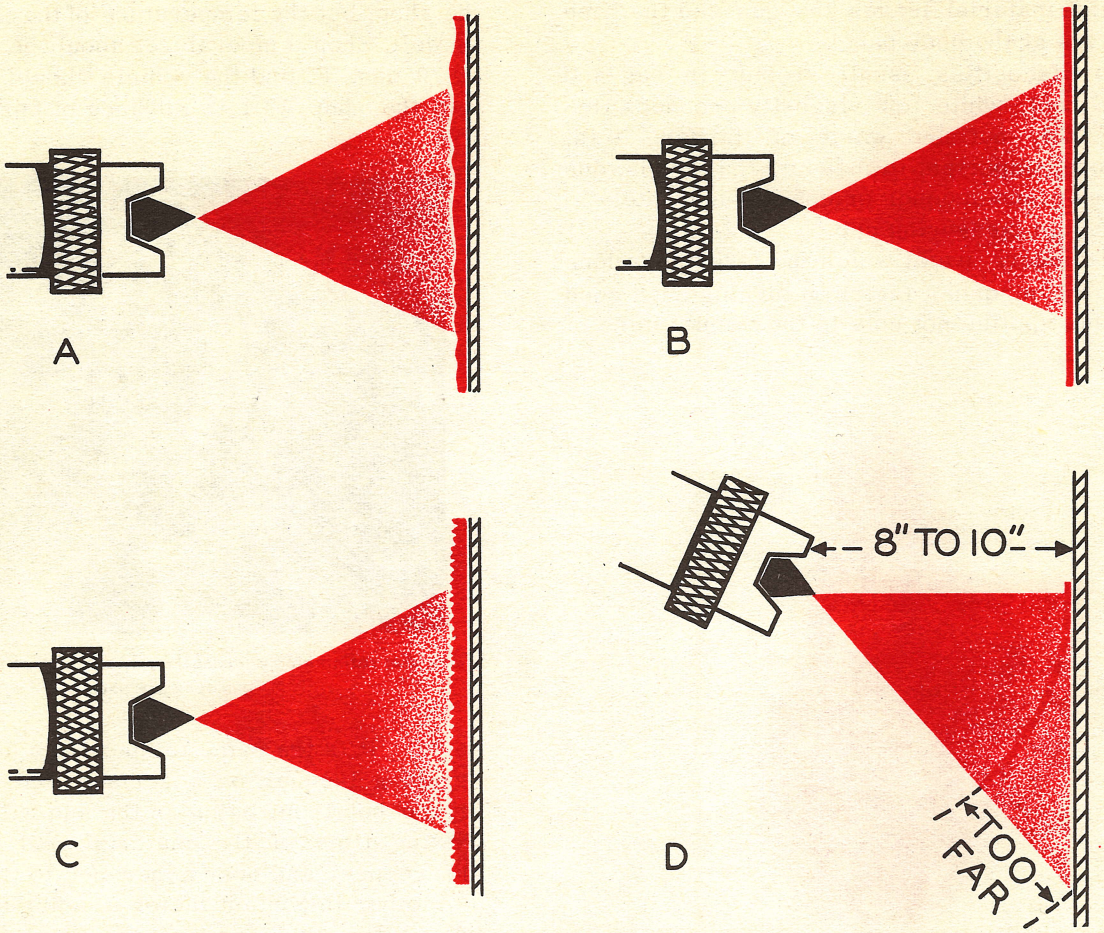


50-69. *For refinishing automobiles, spray guns of the syphon cup gun type are used.*

Another important factor in doing a good paint job is the thickness of the paint film on the surface. Obviously, a thick film takes longer to dry than a thin one, and, as a result, the paint will sag, ripple or orange peel. In the case of enamels, blistering may result.

The painter should, therefore, produce a coat that will remain wet long enough for proper flow-out, but no longer. The amount of material sprayed on a surface with one stroke of a gun will depend on the width of the fan, the distance of the gun from the sprayed surface, the air pressure, and the amount of thinner used. In addition, the speed of the spray stroke will also affect the thickness of the coat. The best procedure is to adjust the gun to obtain a wet film which will remain wet only long enough for good flow-out, and to get the final finish thickness by spraying an additional coat after the first has dried.

Nearly all standard spray guns are designed to give best performance when held at a distance of 8 to 12 in. from the surface to be sprayed. When the gun is held too close, the air pressure tends to ripple the wet film, especially if it is too thick. On the other hand, if the distance is too great, a greater percentage of the thinner will be evaporated in the spraying operation, and orange peel or a dry film will result,



50-70. (A) Heavy coats with sags, ripples, or orange peel may be caused by a dirty air nozzle, gun too close to work, paint too thin, low air pressure, gun movement too slow, or too much overlap. (B) Correct paint application with good flow-out and no orange peel can only be obtained with a clean, properly adjusted gun held at the correct distance from the work. In addition the paint must be correctly thinned, the air pressure must be right and the gun must be stroked at the correct speed and with 50 per cent overlap. (C) Thin coats which are rough, dry and without lustre are caused by using the wrong type air nozzle, spray gun being too far from work, incorrect air adjustment, too fast gun-stroke or insufficient overlap. (D) When guns are fanned or held at an angle to the work, thickness of coat will taper as shown.

because the spray droplets will not have an opportunity to flow together.

It is, therefore, imperative that the gun be held at the specified distance from the work. In addition, it must not be tilted or held at an angle. Care must also be taken that the gun is not swung in an arc, but is moved parallel to the work. The only occasion where it is permissible to fan the gun is on a small spot where it is desired to have the paint thin out over the edges of the area.

The effects of incorrect handling of the spray gun are shown in Fig. 50-70.

For most painting, the conventional spray gun with attached cup is satisfactory, but on many modern bodies which have undercut surfaces it is necessary to hold the gun at such an angle that such a gun cannot be used. For jobs of this nature a gun with a remote or separate cup is necessary.

CLEAN SURFACE REQUIRED

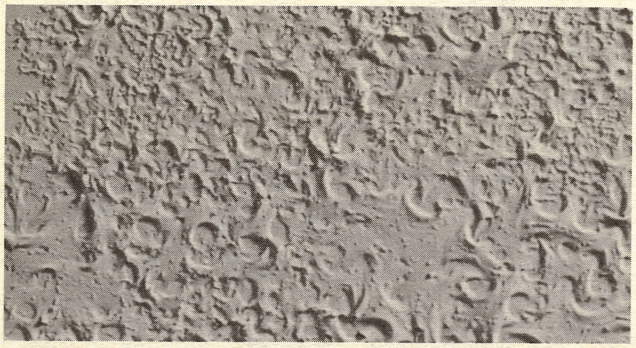
The life and appearance of a repaint job is largely dependent on the condition of the surface to which the finish coats are applied. That is why it is so important to do a good job of straightening the sheet metal, and also to make sure that the rest of the surface of the vehicle is in good condition. The surface must be clean, free from rust, dirt, wax, oil, or other foreign matter; and, in addition, the old paint must have good adherence to the base metal.

So, before starting a refinish job, there are two points which have to be checked before any spraying is done. First, that any original paint has good adhesion and second, that the surface is clean. To check for adhesion, sand a small spot through to the base metal and feather the edges. If the thin edge does not break or crumble it is safe to assume that there is good adhesion. The other point is that the surface must be clean. Old wax, rust, oil film and other foreign material must be removed and the best method is to use one of the special cleaners that are available. Gasoline is not satisfactory, as it will not dissolve any wax that may be present. This should be done before and after the final sanding. The directions accompanying the cleaner should be carefully followed. When wiping the surface, do not use the ordinary shop cloths, as these usually retain a certain amount of grease or other chemicals as received from the laundry. If air is used to blow off dust, the compressor supplying the air must be fitted with a transformer so the air is free of oil and moisture.

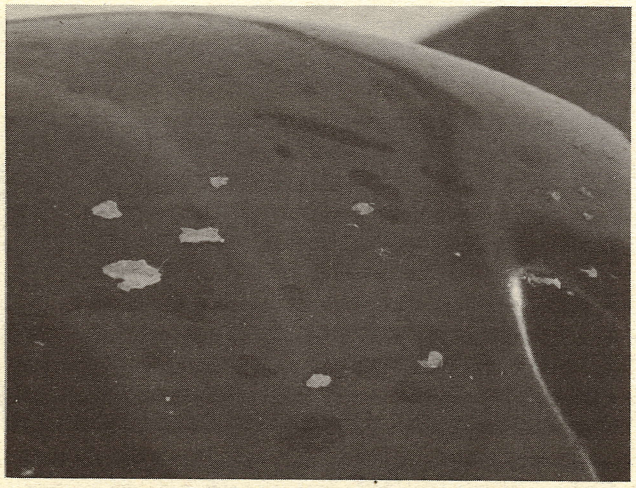
Another important point is that the surface should not be touched by the hands, as the natural oil from the skin will cause poor adhesion and the finish will tend to peel. Examples of paint that has been applied to various types of poorly prepared surfaces are shown in Figs. 50-71 to 84 inclusive.

It is also necessary to determine whether the original finish is lacquer or enamel. A quick check for this is to moisten a finger with lacquer thinner and rub a small area. If the surface is lacquer it will be dissolved.

On lacquer jobs which are to be refinished

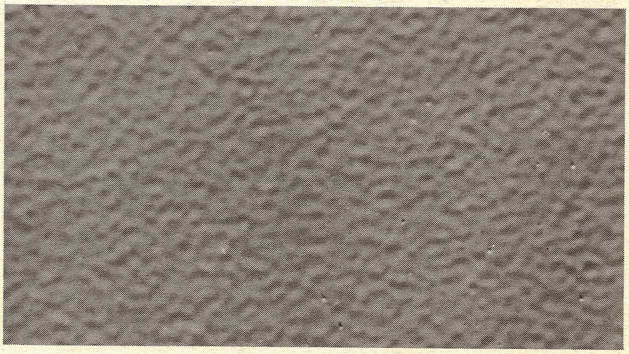


50-71. Lifting—A puckering and wrinkled effect usually resulting from the application of material carrying strong solvents over a partially oxidized surface. It may also be caused by lack of cleanliness, wax, etc. REMEDY: Sand and refinish.

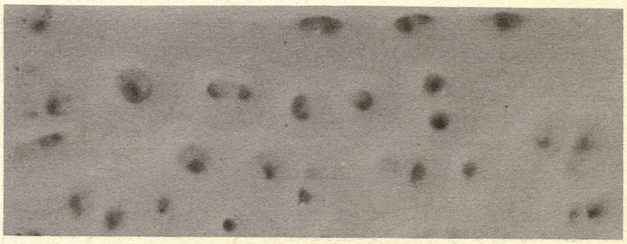


50-72. Bruises and Chipping—Caused by stones, etc., striking the surface and is not due to the finish. REMEDY: Sand out and refinish.

50-73. Peeling Over Solder Spot—Usually noticeable a few weeks after refinishing. Typlified by loss of luster and gets progressively worse until paint peels from surface. REMEDY: After soldering, surface should be washed with a solution of equal parts of ammonia, alcohol, and water. Be sure surface is thoroughly dry before refinishing.

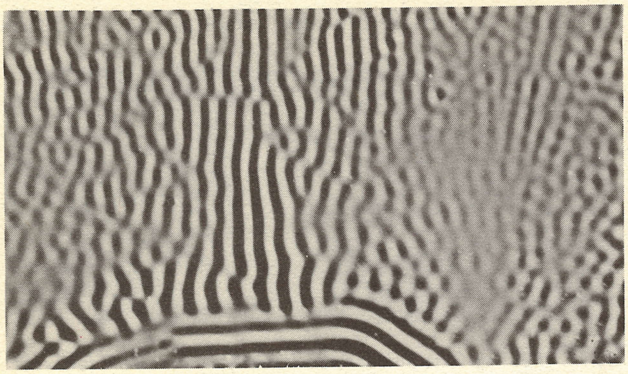


50-74. Orange Peel—This condition may result from a number of causes: improper air pressure at the gun, insufficient reduction and selection of solvent. A thinner that dries too quickly will produce orange peel as will lacquer sprayed on a hot surface. REMEDY: Check thinner, air pressure, and make sure surface temperature is 70 degs.

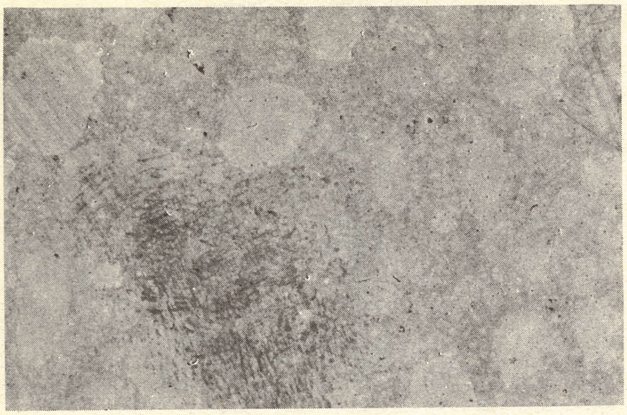


50-75. Fish-eyes—This is usually caused by failure to remove silicone polish. REMEDY: Sand, thoroughly clean surface and then refinish.

with lacquer, it is important to prevent swelling of the old coat. Swelling usually occurs when sanding has been done, and unless the new solvents are prevented from reaching the old finish, no amount of care will prevent the old scratches from showing.



50-76. *Wrinkling—Usually found only in synthetic enamel finish. Results from the application of a heavy coat. Aggravated by high temperatures. REMEDY: Apply thinner coats.*

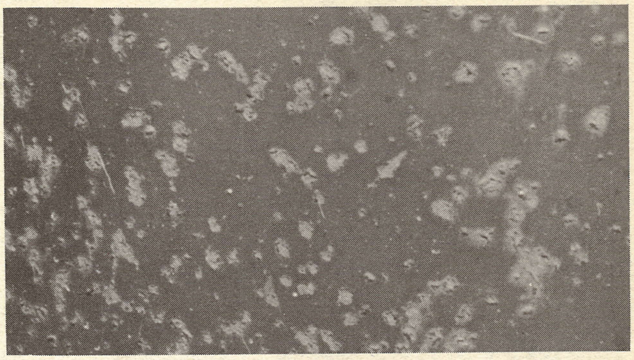


50-77. *Water Spotting—Caused by washing car in bright sunlight. REMEDY: Use paste cleaner and refinish.*

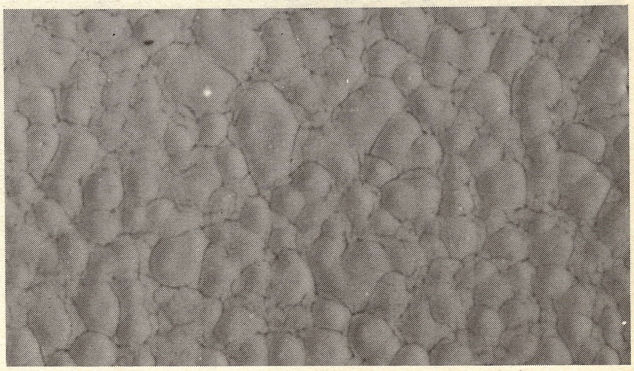
This swelling does not occur on the unmarred or scratched surface of the lacquer which is covered with an insoluble outer layer, but it does occur when the new lacquer contacts the freshly exposed surfaces in the scratches. After all the solvents have evaporated, and the new finish shrinks, small furrows following the scratches will result.

It is, therefore, necessary on lacquer repaint jobs where much of the old refinishing material is not removed, to use a "sealer." This is applied after the necessary sanding and proper treatment of the bare metal. Sealer has good adhesion to the old finish and will prevent penetration of the new lacquer and swelling is prevented. If it is necessary to use any primer surfacer for filling rough spots, this should be applied first and then, after sanding, the sealer is applied.

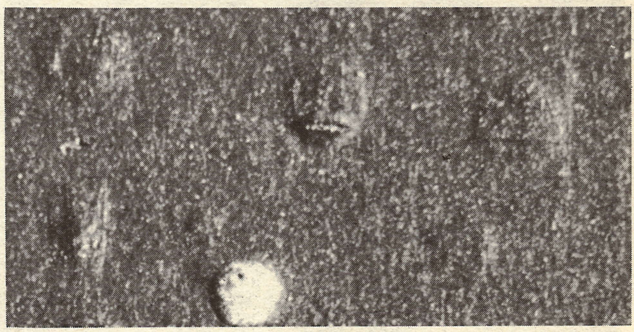
It is necessary to sand enamel finishes carefully, making sure that the abrasive is not too coarse, and that the old finish has been sanded to produce a good surface for the new finish. It is not necessary to use a surfacer if the enamel is in good condition. However, if the old enamel is badly worn and pitted, it is much better to use a surfacer or primer, as much better adhesion and better appearance will be obtained.



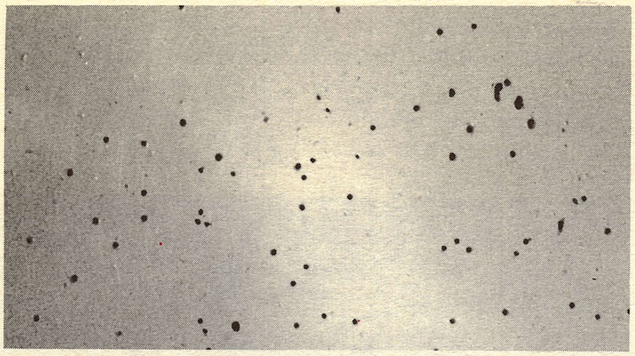
50-78. *Rust under the finish usually appears as a raised section of the finish, or blistering, and is caused by poor penetration and cleaning of the surface. REMEDY: Sand off surface, treat surface with rust remover and refinish.*



50-79. *Pitting—Usually caused by oil or moisture escaping through the air line. REMEDY: Sand down to smooth surface and refinish. Also overhaul compressor and separator.*

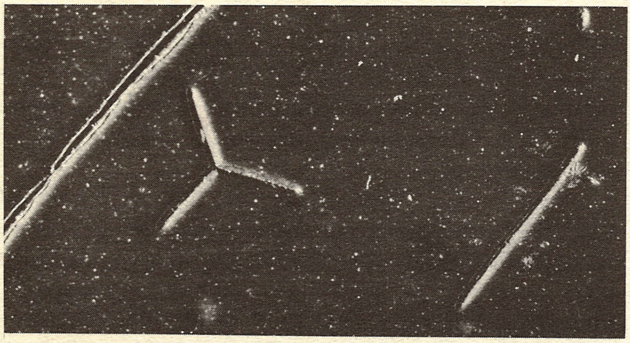


50-80. *Blistering is caused by rust, moisture, oil, grease or other foreign materials working in between coats and causing them to separate. Oil or water in air lines will cause blistering as will high temperatures and high humidity. REMEDY: Remove finish to the metal and refinish.*



50-81. Pin Point Blistering–This type of blistering is often confused with pitting because small broken blisters have the appearance of pits. These pin point blisters range in size from a pin head to a point. REMEDY: Sand down to metal and refinish.

50-82. Paint will have a mottled appearance if applied on surface which had been polished with silicone type polish. It is therefore imperative that all traces of such polish be removed from the surface before refinishing. Another example of paint applied to a surface from which the silicone polish was not carefully removed is shown in another illustration.



50-83. Cracking and checking may extend to the metal. Or, it may go only as far as the undercoating. Depressions in film caused by cracks in the undercoat also are typical. Simple line cracks are caused by temperature stresses, flexing of body panels, second-coat application before first is dry, and poor paint mixing. REMEDY: Remove finish to bare metal and refinish.

Modern primers, glazing putties, fabric patches, cold solder and hot solder will fill almost any rough surface. However, the surface should be as smooth as possible before any of these materials are applied. After the primer and/or other surfacing material is applied, thorough sanding is essential. Many painters recommend three or four grades of paper ranging from coarse to fine. In other words, a No. 16 open coated paper may be used first. This is followed with No. 50 close coated and final sanding is done with No. 150 paper.

Modern surfacing and refinishing materials have greatly simplified automobile painting, but good appearance and long life of the finish is still dependent on the care taken in preparing the surface for the final finish coats.

50-84. Chalking is surface disintegration. It is primarily due to weathering and sunlight and is characterized by dulling and powdering of the surface. REMEDY: Apply paste cleaner followed by polish. In extreme cases, refinishing is necessary.

STEPS IN REFINISHING

LACQUER OVER OLD FINISHES

1. Water sand old finish, using No. 320 paper. Remove old wax or silicone polish with special remover before sanding.
2. Using clean air, blow out all cracks.
3. Clean surface with special grease, rust and wax remover.
4. Spray surfacer on bare metal spots. If necessary, use spot putty or equivalent.
5. Water sand undercoats with No. 320 paper. If any spots are sanded through to base metal, spray again with surfacer and water sand.
6. Seal scratches with special sealer if car was previously finished with lacquer.
7. Blow out cracks with clean air.
8. Again clean surface with special cleaner.
9. Apply lacquer color coats. Three double coats are recommended.
10. Water sand with No. 400 paper.
11. Polish.

ENAMEL OVER OLD FINISHES

1. Remove all wax and silicone polish with special cleaner.
2. Wet sand old finish with No. 320 paper.
3. Clean surface with a special wax, grease and rust remover.

4. Spray on undercoats.
5. Sand undercoats with No. 280 paper.
6. Re-spray undercoats if sanding has gone through to base metal.
7. Re-sand undercoat.
8. Blow out all cracks with clean air.
9. Clean surface with special cleaner to remove hand marks.
10. Wipe surface with tack rag to remove lint and dust.
11. Spray a light coat of enamel over all cracks.
12. Apply a tack coat and follow immediately with a full coat of enamel. If drying lights or oven is not available, allow to dry at least 12 hours in dust-free room.

REMOVING SAND SCRATCHES

Sand scratches have spoiled many jobs which otherwise would have been perfect, and unfortunately the scratches do not show up until after the finish coat has been sprayed.

Of course the basis of any good paint job is smooth metal, and unless the man finishing the metal does a good job, it will be virtually impossible for the painter to fill the scratches so that they will not show. Careless filing or bearing too hard on a coarse disk leaves scratches, gouges, and furrows that are hard to fill.

Many experienced body men will, therefore, use a coarse disk for roughing and cutting down weld spots and high areas only. Then the major part of the sanding is done with a 24 disk and final finishing of the metal with a disk of No. 50 or 80 grit. Even with such care some sand scratches may be made, as there are often small burrs or fins of torn metal along the edges of the sand scratches. Many mechanics have found that it pays to follow up the heavy power sanding with a little hand sanding, using No. 150 paper.

While primers have been vastly improved in their ability to fill and cover a surface, they cannot be depended on to do a job with a single coat. Several coats should be applied and ample time should be allowed for the individual coats to dry. This is much better practice than applying a single heavy coat, as it is difficult to tell when such an application has dried all the way through.

Fine paper should be used when sanding priming coats. Paper such as No. 220 or No. 240 will produce scratches that usually show through the first coats. In some instances such paper can be used for the initial sanding of primers but experienced body men advise the use of No. 320 or 360 with final finish sanding with No. 400 paper.

When lacquer is used to finish the car, the lacquer thinner penetrates the undercoat. Where the undercoat is heaviest, the swelling will be the greatest. The swelling will be still greater if the lacquer is sanded and polished before all the thinner has evaporated. A good practice is to first spray a light fog coat of lacquer as this will reduce the possibility of sand scratch swelling and spoiling the appearance of the finished job.

OPEX
Sherwin-Williams Color Key
OPEX
Automotive

50-85. One type of equipment designed to prepare a desired shade of color.

Scratches can also be caused in the final polishing of the finish coat if care is not exercised in the selection of the rubbing compound. The finer the abrasive in the rubbing coat, the less chance there is of producing any scratches.

When doing spot painting, it is important that the spot be carefully feather edged. It is important to give the area and edge a careful final sanding with No. 360 or 400 paper to eliminate any scratches. If any rubbing compound is used, the area should be cleaned with a good wax and grease remover, as many rubbing compounds contain a lubricant.

Old lacquer surfaces should not be sanded with any paper coarser than No. 360. The reason for this is that when new lacquer is sprayed on the old finish, the lacquer solvents will penetrate any scratches and cause swelling of the original lacquer.

In general, the same care must be used with synthetic enamel. While there are no strong solvents to cause difficulty, as in the case of lacquer, the high lustre of the enamel will tend to magnify any scratches that may be present.

MATCHING COLORS

Even though paint manufacturers have made ready-mixed paints for standard production colors of automobiles available, the number is so great that virtually no jobber carries the complete line. Consequently the painter is often faced with the problem of mixing his own colors.

Matching colors is not easy. Since automobiles are being turned out with ever increasing varieties of shades and tones, paint men are finding their work becoming more difficult. The problem of fading further complicates the situation.

Greatly aiding the paint man in meeting the problem of color matching is the work of various paint manufacturers in providing instructions, specialized equipment and basic colors. One type of equipment designed to prepare paint of a desired color is shown in Fig. 50-85.

Probably the most important point in color mixing is that painters have good color perception. Many color mixing aids are available. These include besides thirty basic colors, mixing containers, stirring paddles, test panels, and color mixing equipment which is being used by an increasing number of shops.

The important thing for the beginner to know is that every color has what is known as a "mass-tone" and a "tint-tone." The mass-tone can be judged from the color as it appears on the painted panel or in the can. The tint-tone of a color is the shade resulting from mixing a small quantity of the color with a large quantity of white. For example, a dark green mass-tone will usually have a blue tint-tone and most maroons have a violet or purple tint-tone. Usually it is impossible to add white to a dark green to get a light green, or white to a maroon to get a light red. Small additions of color will tint according to its tint-tone and large amounts will influence others according to mass-tone.

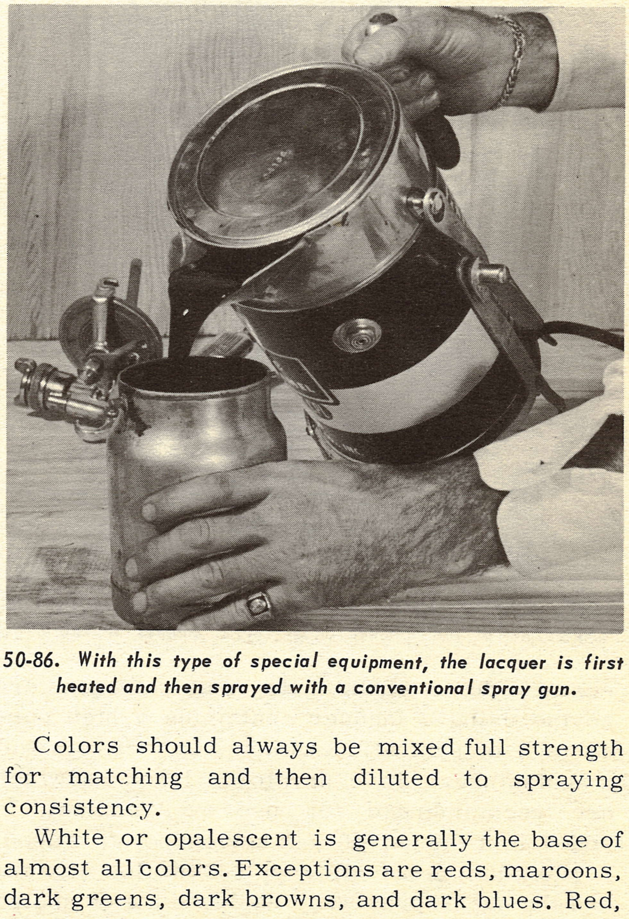
Black, of course, darkens a color and white lightens it. Black tends to dull a shade. Addition of white dilutes the tint.

Clean equipment is, of course, a must when matching colors. Dust, old paint or other material will spoil the desired effect. Before being applied, each basic color or paint must be stirred thoroughly. Mixtures must also be stirred thoroughly. When not in use, cans of paint must be tightly closed to reduce evaporation of the solvents and because of the effect of light. It is also important that matching should be done in sunlight or northern exposure as artificial light changes tints and tones.

As almost all shades darken on drying, wait until the color is dry before making comparisons. When matching a color on a car, it's important that all waxes and polish have been removed as they tend to change the color. Also, when making comparisons it must be remembered that the larger the surface the lighter the color will appear. This is caused by light reflection. Therefore, comparisons of areas of equal size should be made.

A lot of material can be saved if small amounts are first mixed and predominating colors used first. If a formula is being followed, start with the major shade, adding the minor quantities according to volume.

Usually the larger proportion of the formula will provide the desired depth of color, but further toning will be needed to produce the particular shade being matched. Only a very small amount of color is ordinarily required for toning. For example, a touch of red may mean a small quantity on the tip of a spatula added to a quart batch. This touch should be added last.



50-86. With this type of special equipment, the lacquer is first heated and then sprayed with a conventional spray gun.

Colors should always be mixed full strength for matching and then diluted to spraying consistency.

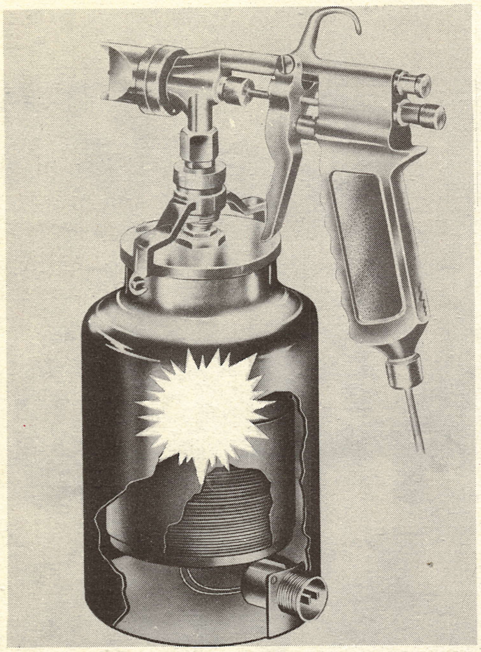
White or opalescent is generally the base of almost all colors. Exceptions are reds, maroons, dark greens, dark browns, and dark blues. Red, blue, yellow and green will impart brightness to a mixture.

TOUCH-UP JOBS ON ENAMEL

There are several different ways of doing spot touch-up jobs on enamel surfaces. Some, of course, are better than others. Time is undoubtedly the determining factor in deciding which one should be used.

First of all, if small nicks and scratches on the edges of doors and fenders are to be touched-up, many shops use lacquer. It is applied by means of striping or other small brushes. As the area to be worked over is small, no sanding or undercoating is necessary because the lacquer adheres to the surrounding enamel. Naturally, a better job would result if the surface were sanded and the painter followed through with undercoat and lacquer. However, that would require considerably more time.

On large areas, (especially if the customer is in a hurry for his car) it is permissible to use lacquer on enamel provided certain precautions are taken. As standard lacquers and enamels do not chalk at the same rate, painters advise using a lacquer containing a high percentage of synthetic enamels. In fact, several manufacturers have developed lacquers which are recommended for use over enamel. In addition, a thinner of high solvent power is used.



50-87. A heating element is built into this gun to maintain the temperature of the lacquer or synthetic enamel at 160 degs.

Maximum gloss will result from this mixture and the over-spray will blend into the enameled areas beyond the repainted spot. Some painters advise spraying a final coat of lacquer, thinned twice as much as usual, as a mist coat for the entire area.

After repairing a baked enamel finish with lacquer, compounding may be necessary in some cases. However, it is important to avoid harsh, scratchy abrasives. A mild compound will help to "blend in" the spot and the possibility of "graying" the enamel will be avoided.

The best repair medium for a baked enamel finish is, of course, enamel. This is particularly true where large areas are involved and when some metal work and sanding is necessary. Naturally, the use of enamel will require more time but this can be reduced if infra-red drying lights are used. When enamel is used, the area to be painted is prepared in the usual way and the undercoat sanded down to the level of the surrounding enamel finish. A lacquer primer surfacer may be used as undercoat. Many painters, though, prefer a synthetic resin base primer.

HOT LACQUER

Cars have also been refinished by spraying with hot lacquer. While use of lacquer is being to a degree superceded by acrylic for refinishing, use of hot lacquer has certain advantages over spraying at room temperature and these advantages are said to out weigh cost of additional equipment and special care that is required.

First of all, hot spraying differs from the normal application of lacquer and synthetic enamel in that the paint is heated before spraying. This is accomplished by means of special heating units, Figs. 50-86 and 87, designed to maintain the temperature of the paint at 160 deg. In addition, a special air cap and nozzle for the spray gun should be used to obtain the best results.

By heating the lacquer or synthetic enamel to 160 deg., its viscosity is reduced from a third to a fourth of its value at 70 deg. Since this temperature is maintained at all times during the operation, the viscosity will be constant, regardless of the temperature of the shop. This is an important advantage, as every refinisher knows the difficulties encountered when shop temperatures vary.

In conventional spraying, lacquer strikes the car surface at from 20 to 25 deg. below shop temperature, and when the shop is cold or damp, blushing results.

When paint is sprayed at 70 deg., nearly 50 per cent of it is lost, but when spraying hot lacquer at 25 to 35 lb. pressure, or hot enamel at 35 to 45 lb. pressure, virtually all of it gets to the surface being sprayed and stays there.

Shops that have used hot spraying have found it saves both time and money. As less thinner is required more lacquer or enamel reaches the surface being painted. In normal cold spraying, lacquer is reduced from 100 to 150 per cent with thinner so that the solids comprise only about 16 to 20 per cent. In hot lacquer work, the material is reduced with thinners to about 50 per cent. The addition of heat results in 25 to 30 per cent solid matter at the spray nozzle. In other words, with hot spraying, about one and a half times more solid matter reaches the surface than with cold spraying.

As a result, refinishers have found that a lacquer job can be done on a medium size car with two coats, cross sprayed, and use only 2 to 2 1/2 qts. of material. An enamel job on the same size car requires only 2 qts. In other words, one double or cross coat of hot lacquer is equivalent to four or five coats of lacquer sprayed in the conventional manner.

In addition to the fact that about one-half the number of coats of lacquer are required, hot spraying has the advantage of quicker drying time. Lacquer applied by hot spray is out of dust in about 15 to 20 min., and out of tack in from 30 to 45 min. Hardness of film is obtained in about 8 to 10 hours.

Additional toughness is obtained which is not apparent in cold application. After 8 to 10 hours drying, the lacquer can be compounded for added beauty and depth of color. In fact, sanding and rubbing of lacquer is reduced to a minimum, and polishing and compounding of enamel is eliminated.

There are many other advantages of hot spraying. The elimination of blushing has already been mentioned. The quicker drying time results in less dirt in the final finish. Material costs are about 13 1/2 per cent lower, and the reduced time per job permits more jobs per week. Orange peel and overspray are also avoided, and the tendency to sag is reduced. If orange peel occurs, it can be compounded.

Hot lacquer dries with a higher gloss, often equal to synthetic enamel. If compounding is necessary, less time and effort is required. In many cases, polishing or dry buffing is all that is necessary. Similarly, when hot enamel is used, a more uniform and brilliant gloss is obtained.

In regards to the amount of thinner required, this varies with climatic conditions and the characteristics of the thinner. For normal conditions, some manufacturers recommend three parts of thinner to one part of lacquer. As shop temperatures increase, less thinner is required.

Spray gun manufacturers have special air caps and nozzles for their spray guns which are used for hot spraying, and several companies have developed heating units. For spotting, electrically heated cups which can be attached directly to the spray gun are available. For complete paint jobs other units are available which rapidly heat the lacquer to the desired temperature and maintain it at that point, Fig. 50-87. The hot lacquer can then be poured into the regular spray cup as needed, Fig. 50-86.

REFINISHING WITH ACRYLIC LACQUER

One of the newer refinishing materials is acrylic lacquer. This is available under various trade names such as Duracryl, Lucite, Dytho-Lac, Alpha, Opex Acrylic and of course Acrylic coupled with the manufacturers name. According to the manufacturers, acrylic lacquers withstand sun and extreme weather conditions better than the conventional lacquers and enamels. In addition they have a high lustre which they retain without polishing.

Acrylic lacquer is used by a number of car factories in finishing their cars. In using acrylic lacquers certain precautions are necessary.

Cars finished with acrylic lacquer should not be polished or waxed for at least 60 days after delivery. In fact polishing is usually not needed for at least 18 months. Furthermore, because acrylic lacquer is so extremely hard it is nearly impervious to staining from oil and gasoline. Another point emphasized by the manufacturers is that conventional washing is all that is necessary to remove road film and maintain the original high gloss.

Particular care must be exercised when removing road tar from a car finished with acrylic lacquer as many of the tar removers while highly satisfactory on ordinary lacquer and enamel will cause spotting and dissolve the acrylic finish.

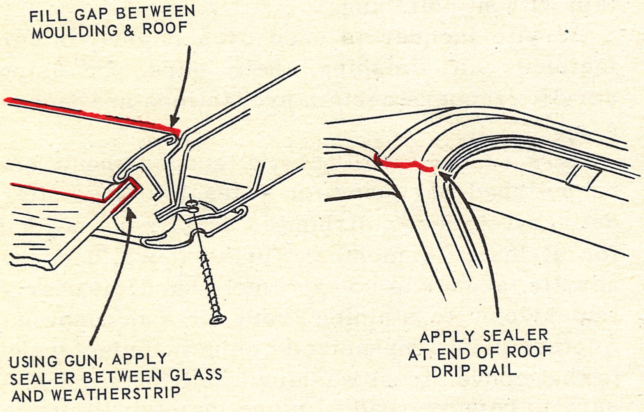
Acrylic should not be used to repair cars finished with conventional lacquer. Even with a sealer between the lacquer color and the acrylic, cracking failures will occur in a short time. It is always advisable to refinish a car with the same type of material as was used for the original finish. This applies particularly to acrylic.

Enamel should never be sprayed directly over acrylic because of early failure. If desired, a sealer should be first sprayed over the acrylic, and then the enamel applied over the sealer. However, enamel should not be used for spot repair over acrylic.

If acrylic is not available for spot repairs, lacquer may be used, but the durability is not equal to that of acrylic. If lacquer is used to repair acrylic, the acrylic should be sanded lightly and the lacquer applied to complete panels.

If it is desired to completely refinish or two-tone a car previously finished with acrylic, standard lacquer may be used provided the original acrylic is sanded to almost complete removal, or to a point where the undercoat is showing over at least 90 per cent of the area. If this is not done objectionable softening may occur. Note that it is not necessary to sand the surface to the bare metal.

When repairing the finish of cars finished with acrylic lacquer, the temperature of the refinishing room should not be less than 65 deg. If refinishing is attempted at a lower temperature, a cracked condition will result. Another must is the acrylic lacquer must be stirred or the container shaken before and during use. Acrylic lacquer contains a large amount of aluminum flake material and unless it is agitated, the aluminum will settle out and the finished appearance will not be uniform.


FILL GAP BETWEEN MOULDING & ROOF
USING GUN, APPLY SEALER BETWEEN GLASS AND WEATHERSTRIP
APPLY SEALER AT END OF ROOF DRIP RAIL

50-88. *Areas around windshield where leaks may occur.*

Before spraying the surface, all traces of wax, polish and grease must be removed. This should be done with a cleaner designed for the purpose. The next step is to wipe the surface dry with a clean cloth.

The edges of the area to be refinished should then be cut with coarse abrasive paper. Then feather the edges with No. 400 abrasive paper. On new metal a metal conditioner should be used. Then wash with water and dry.

The surface is now ready to be sprayed with primer surfacer and the instructions for thinning given by the manufacturer should be followed. Heavy coats should not be applied. Instead use two or three medium coats, allowing each coat to become dull and dry for at least 30 minutes, before applying the next coat.

The next step is sanding. If dry sanded, use No. 360 paper, or if wet sanding is preferred, use No. 400 paper. Any imperfections in the surface should be filled with putty. After two hours drying time, the surface is again sanded, and then sealed with a light coat of primer surfacer.

In spot area repairs, the edge of the area should be rubbed with rubbing compound to remove overspray.

The acrylic finish lacquer is then sprayed, and three or four wet double coats should be applied. Allow each coat to "flash" before applying the next coat. In spot repair, extend each color coat a little beyond the previous coat to blend into surrounding finish. Some factories then advise a spray mist coat of thinner to improve leveling and gloss.

If possible, allow the surface to dry for at least 10 hours. However, in an emergency four hours should be enough. If infrared lights or oven are available it can be force dried for at least 10 minutes at 180 deg. F. Process the surface with either hand or machine rubbing, followed by a dry buffing with a lamb's wool bonnet. A light sprinkle of a few drops of water will improve the lustre. However, to avoid loss of lustre, it is not advisable to buff until two weeks after spraying.

WATER AND DUST LEAKS

The location and repair of water and dust leaks in automobile bodies is an important part of the duties of every body repair man.

In many cases such leaks result from the dislocation of weather stripping and are easily located and repaired. In other cases, special effort and procedures are needed to locate, and then repair the difficulty.

If the exact location of the source of a leak is not known, the first step is to inspect the general area of the leak for watermarks, rust or dust trails, and trace these back to the source or beginning. If there are no such indications, a mechanic can sit in the car, while water is sprayed over the outside of the suspected leak point area. The mechanic, inside the car can then see where the water is entering. In some cases it may be necessary to remove head lining or other trim to locate the source of the leak.

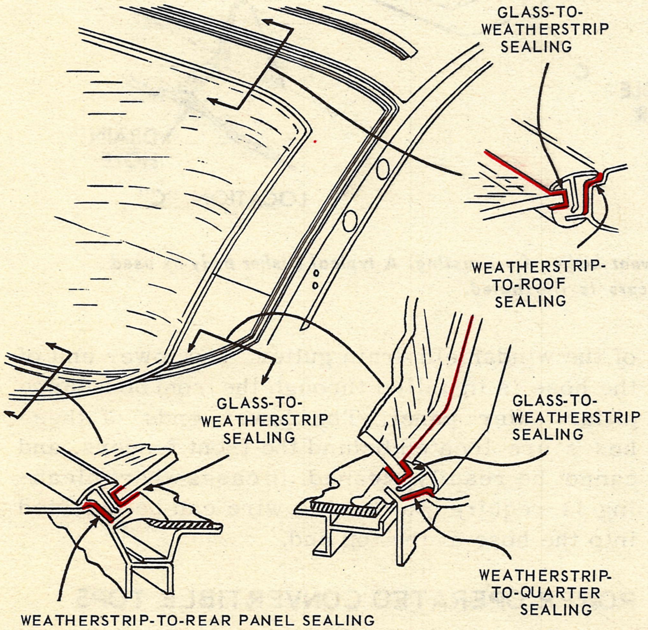
Another method of locating leaks is to fill a syringe with powdered chalk, water, or a mixture of the two. Such syringes can be purchased at any drug store and the powdered chalk at most hardware stores. The suspected leaky seam is then sprayed with the contents of the syringe and the dust trail formed by this operation will quickly show the actual point of entry of the rain and dust.

A variety of materials are used for correcting water and dust leaks. Such materials include:

- Black caulk and sealer
- Gray caulking cord
- Auto body sealer
- Rubber cement
- Metallic caulk and sealer
- Pressure gun for applying caulk
- Sponge rubber stripping

Before attempting to repair any leaks around doors or deck lids, it is important to make sure that the doors and lids are correctly fitted as poor fits invariably result in water and dust leaks. The easiest method of checking the fit of doors and deck lids is to note that the edges of the door or lid are the same distance from the surrounding body panel. When that has been corrected, slide a feeler gauge (approximately .005 in.) along the weather strip with the door or deck lid closed. If no resistance is noticed to the passage of the feeler gauge blade, leakage will occur at that point. Such leaks can be repaired by the installation of new weather stripping which is cemented in place with the appropriate sealer.

Leaks around the windshield can usually be repaired by means of the pressure gun filled with black caulk and sealer. The procedure is to slide the nozzle of the pressure gun between the rubber and the glass and force the compound as indicated in Fig. 50-88. The same illustration shows the area to apply the sealer when leaks occur between the windshield weather strip, and the body flange.

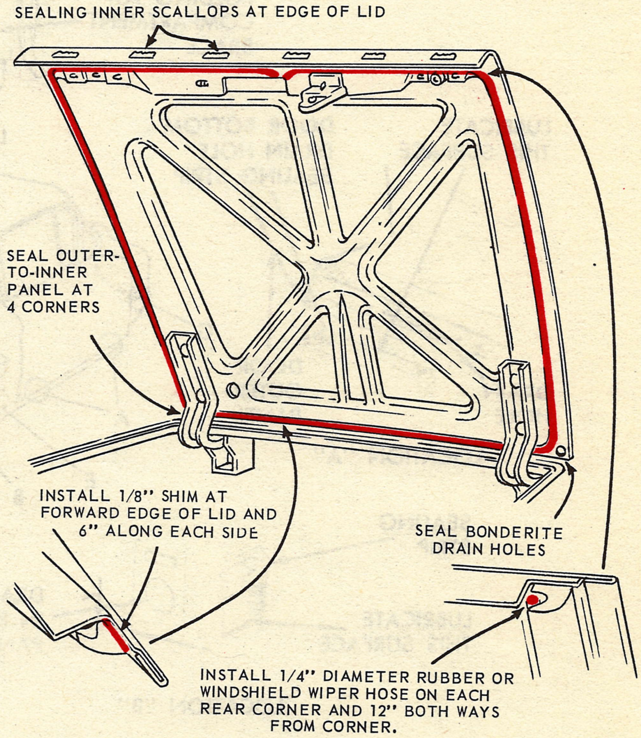

GLASS-TO-WEATHERSTRIP SEALING
WEATHERSTRIP-TO-ROOF SEALING
GLASS-TO-WEATHERSTRIP SEALING
GLASS-TO-WEATHERSTRIP SEALING
WEATHERSTRIP-TO-QUARTER SEALING
WEATHERSTRIP-TO-REAR PANEL SEALING

50-89. Showing where caulking may be needed around rear windows to overcome leaks.

It should be emphasized that in some cases of leaks around the windshield or rear windows, that the difficulty be overcome only by removing the glass and then replacing it, using ample sealing compound. Areas where leaks may occur are indicated in Fig. 50-89.

Leaks may also occur through bolt and nut holes used to attach chrome trim to the body panels. In such cases the difficulty can be overcome by applying special sealer to each of the clips and nut ends.

Fig. 50-90 shows the location of the weather stripping of a deck lid. In some instances it will be necessary to build up the existing weather stripping by means of 1/8 in. thick weatherstrip rubber. Leakage may also occur around deck lid locks. In such cases, install a small rubber washer on the lock cover shaft, between the lock housing and the spring.


SEALING INNER SCALLOPS AT EDGE OF LID
SEAL OUTER-TO-INNER PANEL AT 4 CORNERS
INSTALL 1/8" SHIM AT FORWARD EDGE OF LID AND 6" ALONG EACH SIDE
SEAL BONDERITE DRAIN HOLES
INSTALL 1/4" DIAMETER RUBBER OR WINDSHIELD WIPER HOSE ON EACH REAR CORNER AND 12" BOTH WAYS FROM CORNER.

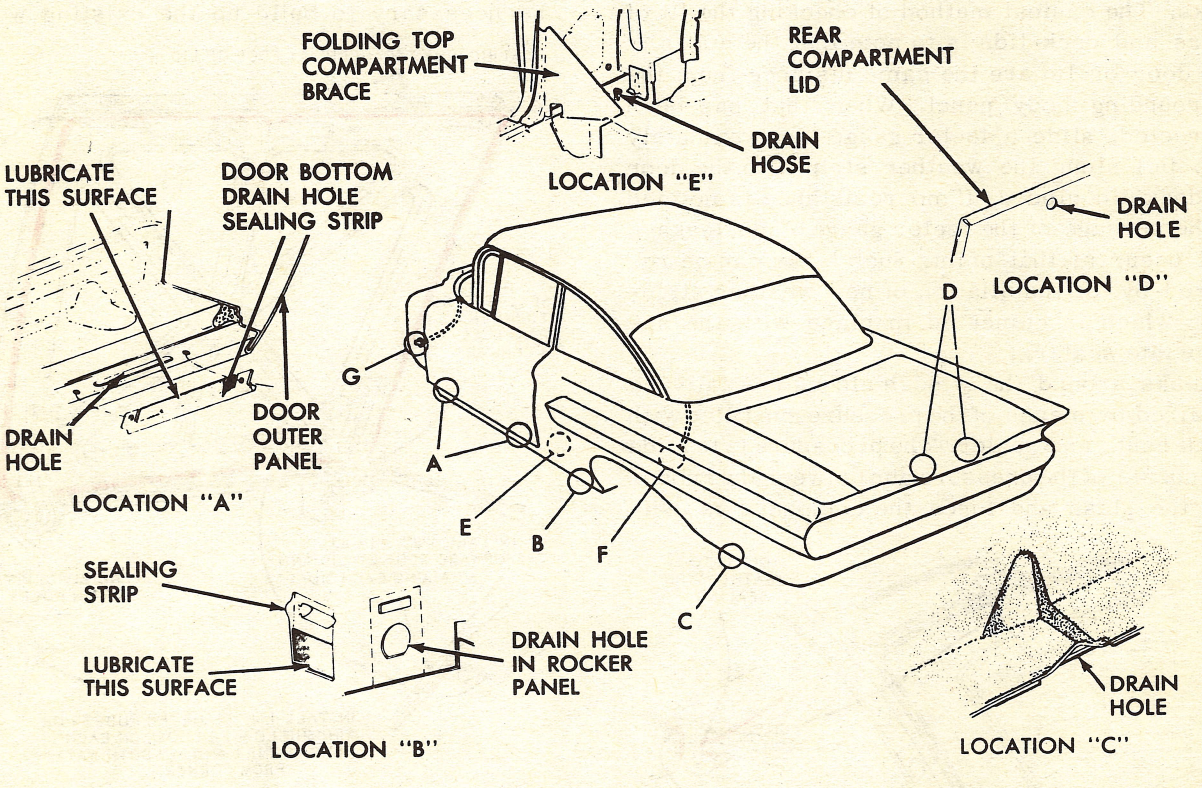
50-90. Rear deck lids may leak at the points indicated.

When water leaks into the passenger compartment around the doors and cowl hinge pillar, it is important to make sure that all the drain holes on the bottom of each door are open. Also remove the door trim panel, and inspect the bottom edge of the water shield for proper sealing to the door. A good seal must be maintained completely around the water shield. Check by pouring water into the door at the belt line, to make sure that none of it will splash past the water shield.

Leaks at the cowl hinge pillar may be corrected by installing a drain tube inside each hinge pillar.

BODY WATER DRAIN LOCATIONS

Automobile bodies are designed with provisions for draining water that normally enters certain areas of the body. The locations of the drain holes on a typical Fisher body as used on General Motors cars is shown in Fig. 50-91. It is important that these drain holes be cleaned periodically to insure proper drainage.


FOLDING TOP COMPARTMENT BRACE
DRAIN HOSE
LOCATION "E"
REAR COMPARTMENT LID
DRAIN HOLE
D
LOCATION "D"
LUBRICATE THIS SURFACE
DOOR BOTTOM DRAIN HOLE SEALING STRIP
DRAIN HOLE
DOOR OUTER PANEL
LOCATION "A"
G
A
E
B
F
C
SEALING STRIP
LUBRICATE THIS SURFACE
DRAIN HOLE IN ROCKER PANEL
LOCATION "B"
DRAIN HOLE
LOCATION "C"

50-91. It is important to keep body drain holes open to prevent bodies from rusting. A typical Fisher body as used on General Motors cars is illustrated.

Each door is provided with two drain holes A, Fig. 50-91, which are located along the bottom of the door. Each hole is covered by a sealing strip which prevents dust entry into the body. The shaded surface of the sealing strip should be lubricated periodically to prevent the strip from sticking to the metal.

A drain hole B is located in the rocker inner panel beneath the rear quarter window area, and is covered by a sealing strip to prevent entrance of dust. The shaded surface of this strip should be lubricated to prevent the strip from sticking to the metal.

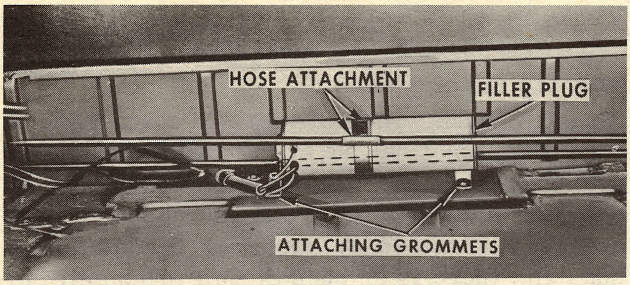
Another drain hole C is located behind the rear wheel housing panel, and is formed in the rear quarter outer and rear compartment filler panel pinchweld flange.

Each deck lid is provided with two holes D and provide drainage for any moisture that may collect in the lid inner construction. Convertible models are provided with a drain hole at E. This is provided with a short drain hose to prevent the entrance of dust. A drain hose F is located at each outer corner of the back window drain gutter. The lower end of the hose is installed through the underbody adjacent to the wheel house panel.

A drain hose G is located at each outer corner of the windshield drain gutter. The lower end of the hose is installed through the front body hinge pillar outer panel. The lower ends of these hoses are located behind the front fenders, and cannot be readily cleaned. In cases where cleaning is required, a flexible wire can be inserted into the hose at the top end.

POWER OPERATED CONVERTIBLE TOPS

To raise and lower the tops of convertible cars, a high pressure hydro-electric system is



50-92. Motor and pump assembly for power operated folding tops.

used by some manufacturers. By means of such a system, the top (after being unlatched and raised above the windshield by hand) can be lowered and raised by actuating a control switch on the instrument panel. Hydraulic fluid from an electrically driven pump (usually located behind the back of the back seat back rest) is forced through tubing to the double acting piston type cylinders located at each rear quarter section of the car. Pressurized fluid entering the top of the lift cylinders forces the pistons down, thus lowering the top.

When the control on the instrument panel is operated in the reverse manner, the pressurized fluid enters the bottom of the hydraulic cylinders, forcing the pistons upward, thus raising the top.

The hydro-electric unit consists of a 12 v. reversible type motor, a rotor type pump, two hydraulic lift cylinders, and an upper and lower hydraulic hose assembly. One type motor and pump assembly is shown in Fig. 50-92.

The Hydraulic System: To fill the hydraulic system, heavy duty brake fluid is used. The top must be in the raised position. A filler plug adapter as shown in Fig. 50-93 is installed in place of the filler plug at the end of the unit. The filler plug adapter is then connected to the container of hydraulic fluid by means of rubber tubing. The container must be placed in the rear compartment area of the body, and below the level of the motor pump assembly.

Then operate the top to the down position and continue to operate for 10 to 15 seconds after the top is fully lowered, or until the noise level of the pump is noticeably reduced. Reduction in pump noise indicates that the hydraulic system is being filled with fluid.

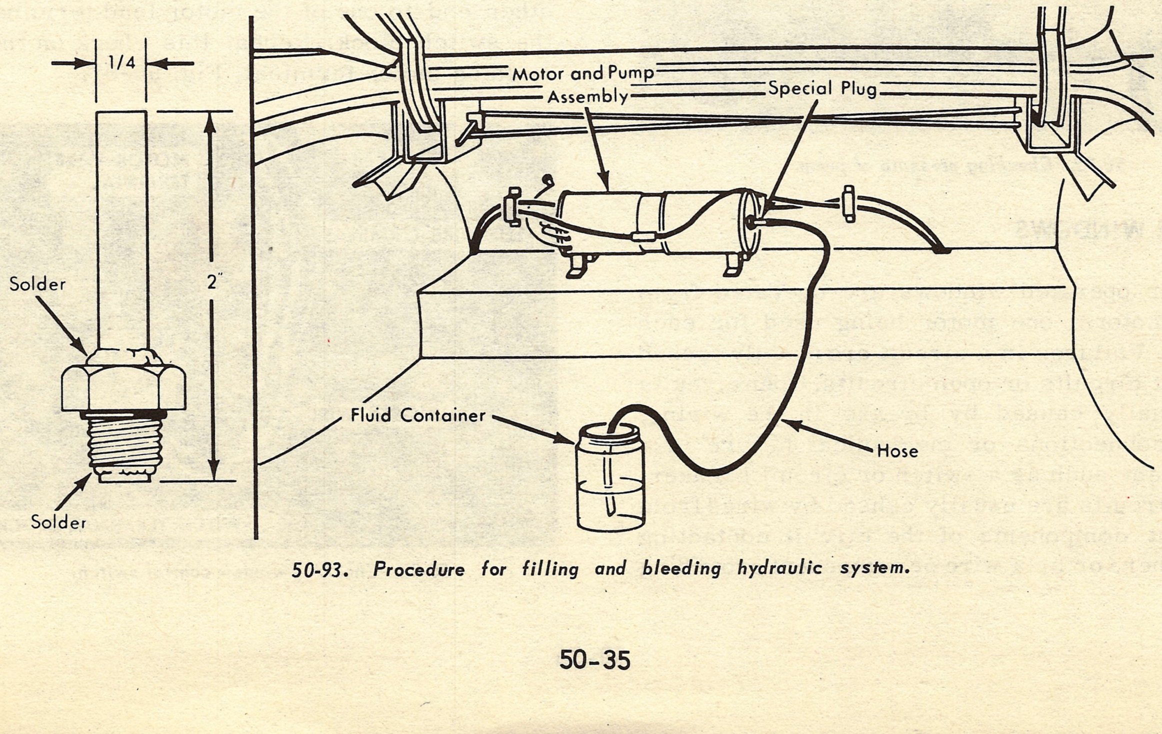
Operate the top several times, or until the operation of the top is consistently smooth in both up and down cycles. When that has been attained, remove the adapter and replace filler plug. Fluid level should be 1/4 in. below lower edge of filler plug opening.

The above procedure is also used to bleed the system of air. At all times, care must be exercised that the hose is always below the surface of the fluid in the container.

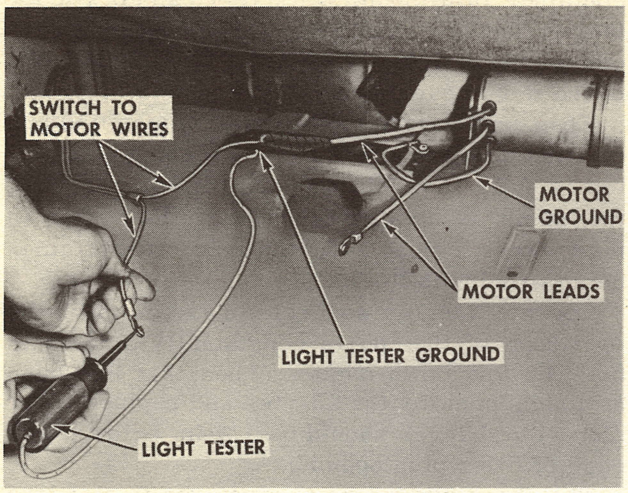
Electrical Checks: A failure in the electrical system may be caused by a low battery, break in the wiring, faulty connections, short circuits, etc.

Checks for current, shorts and opens are made in the usual manner by means of a 12 v. test lamp or a voltmeter as explained in the electrical section of this Encyclopedia. Fig. 50-94 shows the motor leads being checked with a light tester.

Lift Cylinders: To check the operation of the lift cylinders, operate the folding top switch and observe the lift cylinders during "up" and "down" cycles. If the movement of cylinder is not coordinated, or sluggish when motor is actuated, check the hydraulic hoses from motor and pump to cylinder for kinks or other defects. If one cylinder rod moves slower than the other, the



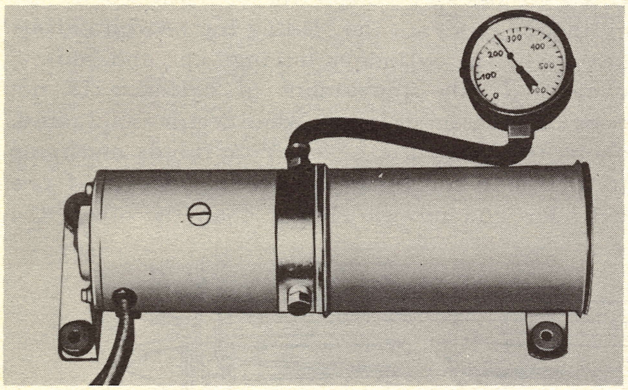
50-93. Procedure for filling and bleeding hydraulic system.



50-94. Checking motor wiring.

cylinder having slower moving rod is defective and should be replaced. If both cylinder rods move slowly, or not at all, replace both cylinders.

Pump Pressure: To check pump pressure, remove motor and pump assembly from rear compartment and install a plug in one port and a pressure gauge in the other port, Fig. 50-95. Operate motor by connecting to 12 v. battery and pressure gauge should indicate 340 to 380 psi. Then check pressure in other port. Reading for both ports must be within specified values.



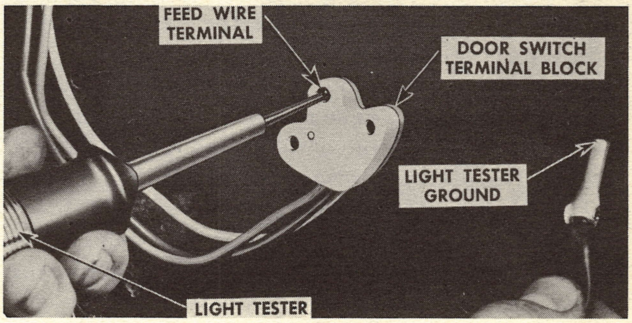
50-95. Checking pressure of pump.

POWER WINDOWS

Power operated windows are operated from 12 v. motors, one motor being used for each window. Failures in a circuit are usually caused by short circuits or open circuits. Open circuits are usually caused by breaks in the wiring, faulty connections or mechanical failure in a component such as a switch or circuit breaker. Short circuits are usually caused by wires from different components of the circuit contacting each other, or by a wire or component grounding on the metal of the body due to a screw being driven through the wire, insulation cut through by sharp metal edge, etc.

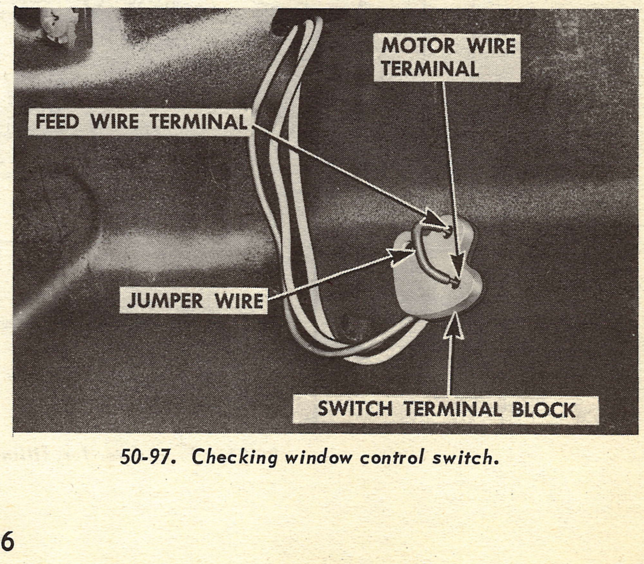
Circuit Breaker Feed Circuit: To check the feed circuit continuity at the circuit breaker, connect one test light lead to battery circuit of circuit breaker and ground the other lead. Circuit breaker is located at fuse block. If tester does not light, there is an open circuit in feed circuit to breaker. To check circuit breaker, disconnect output feed wire from breaker and check terminal from which wire was disconnected with test light. If tester does not light, circuit breaker is defective.

Window Control Switch Circuit: To check feed circuit continuity at window control switch, connect one test light lead to feed terminal of switch block and ground other lead of tester to body metal, Fig. 50-96. If tester does not light, there is an open or short circuit between switch and power source.

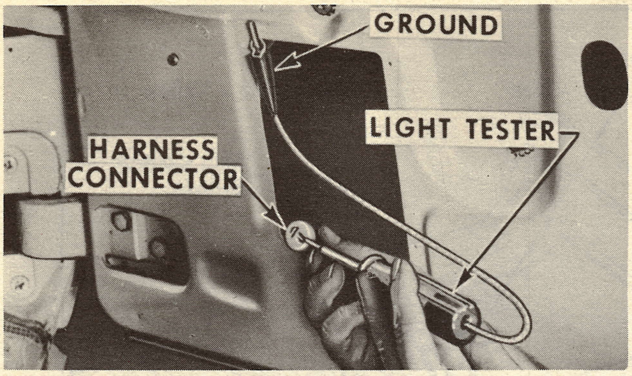


50-96. Checking for current at door window switch.

Window Control Switch: To check the condition of the window control switch, insert one end of a 12 ga. jumper wire to switch feed terminal, and other end to one of the motor lead terminals in the switch block. Repeat this check on the remaining motor terminal, Fig. 50-97.



50-97. Checking window control switch.


GROUND
LIGHT TESTER
HARNESS CONNECTOR

50-98. Checking circuit between switch and motor.

Door Window Switch and Motor: To check the wires between door window switch and door window motor, disengage harness connector from window motor connector. Thumb release on harness connector must be depressed before it can be disengaged from motor. Insert one end of a 12 ga. jumper wire to switch feed terminal and other end to one of the motor lead terminals in switch block, Fig. 50-97. With a test light check for current at motor connector terminal being checked, Fig. 50-98. If tester does not light, there is an open circuit or short circuit in wiring harness between control switch and motor connector.

MANUALLY AND ELECTRICALLY OPERATED SEATS

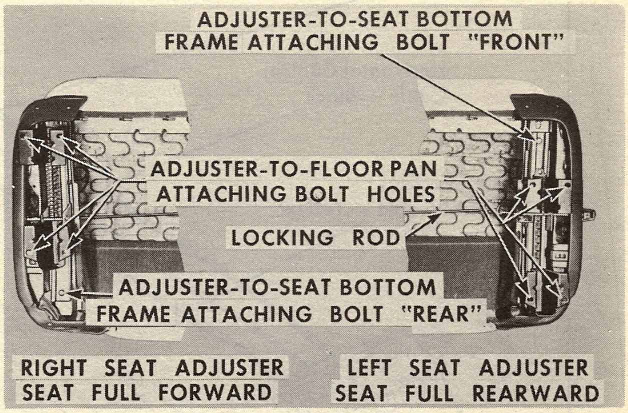
For greater comfort of passengers the front seats of passenger cars are made adjustable. Some are adjusted manually; others are adjusted electrically.

Details of a manually adjustable front seat as used on many Fisher body cars is shown in Fig. 50-99. In this type of construction, the seat can be moved forward or to the rear after depressing a knob at the left of the seat which locks the adjustment.

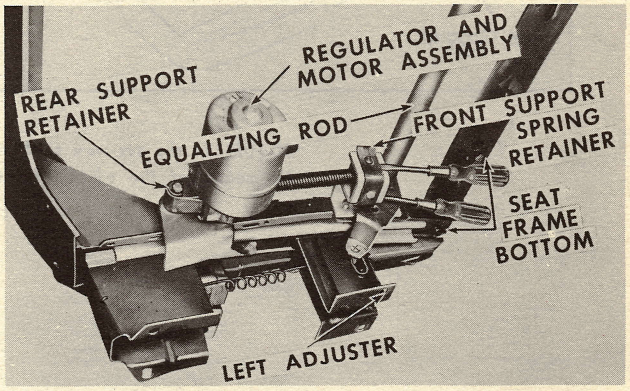
One type of electrically operated front seat provides fore and aft movement of the seat, Fig. 50-100, while another type, known as the six-way seat, Fig. 50-101, provides forward, rearward, upward, downward or tilting of the seat.

On the two-way seat, Fig. 50-100, difficulties may be encountered as the result of misalignment, or wear of the various parts. Such troubles are easily located by observing the operation of the seat. Electrical troubles may also be experienced. These can be traced by means of the familiar test light or voltmeter. If current is found to be reaching the electric motor, but the seat still does not operate, the motor is defective and should be replaced.

Similar troubles may be experienced in the six-way seat, Fig. 50-101. In this design, the seat adjuster operating mechanism incorporates a transmission assembly which includes three solenoids and six drive cables leading to the seat adjusters. Solenoid No. 1, Fig. 50-101, controls the vertical movement of the rear edge of the seat. Solenoid No. 2 controls the horizontal movement of the rear edge of the seat. Solenoid No. 3 controls the vertical movement of the front edge of the seat. In addition to the six seat adjuster drive cables at the transmission assembly, a motor drive cable is installed from the motor to the transmission assembly.

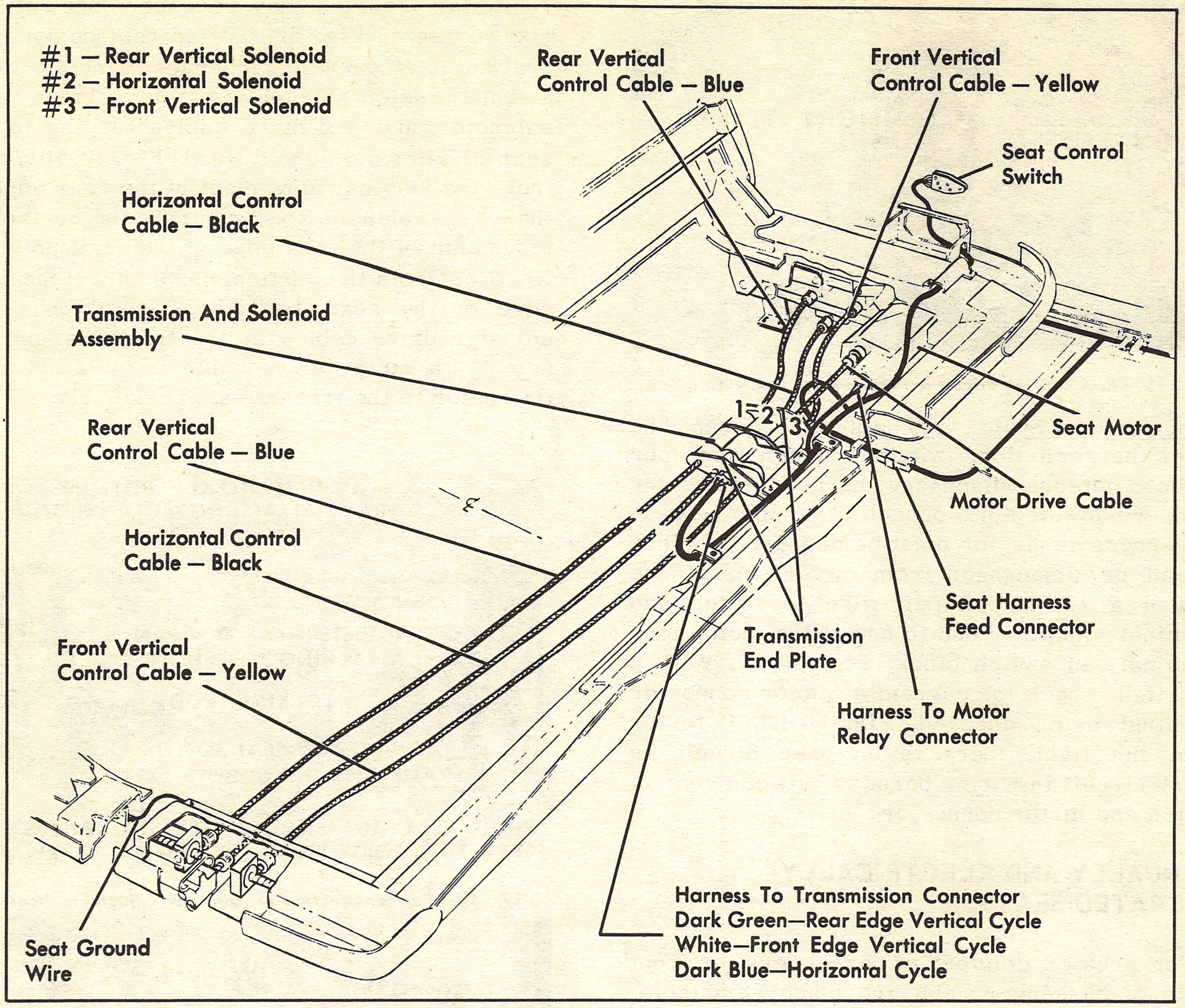

ADJUSTER-TO-SEAT BOTTOM FRAME ATTACHING BOLT "FRONT"
ADJUSTER-TO-FLOOR PAN ATTACHING BOLT HOLES
LOCKING ROD
ADJUSTER-TO-SEAT BOTTOM FRAME ATTACHING BOLT "REAR"
RIGHT SEAT ADJUSTER SEAT FULL FORWARD
LEFT SEAT ADJUSTER SEAT FULL REARWARD

50-99. Showing construction of manually adjustable front seat.


REAR SUPPORT RETAINER
REGULATOR AND MOTOR ASSEMBLY
EQUALIZING ROD
FRONT SUPPORT SPRING RETAINER
SEAT FRAME BOTTOM
LEFT ADJUSTER

50-100. Details of two-way electric seat adjuster, showing screwdrivers being used to pry open seat adjuster regulator front support spring retainer to disengage jack screw nut from support.

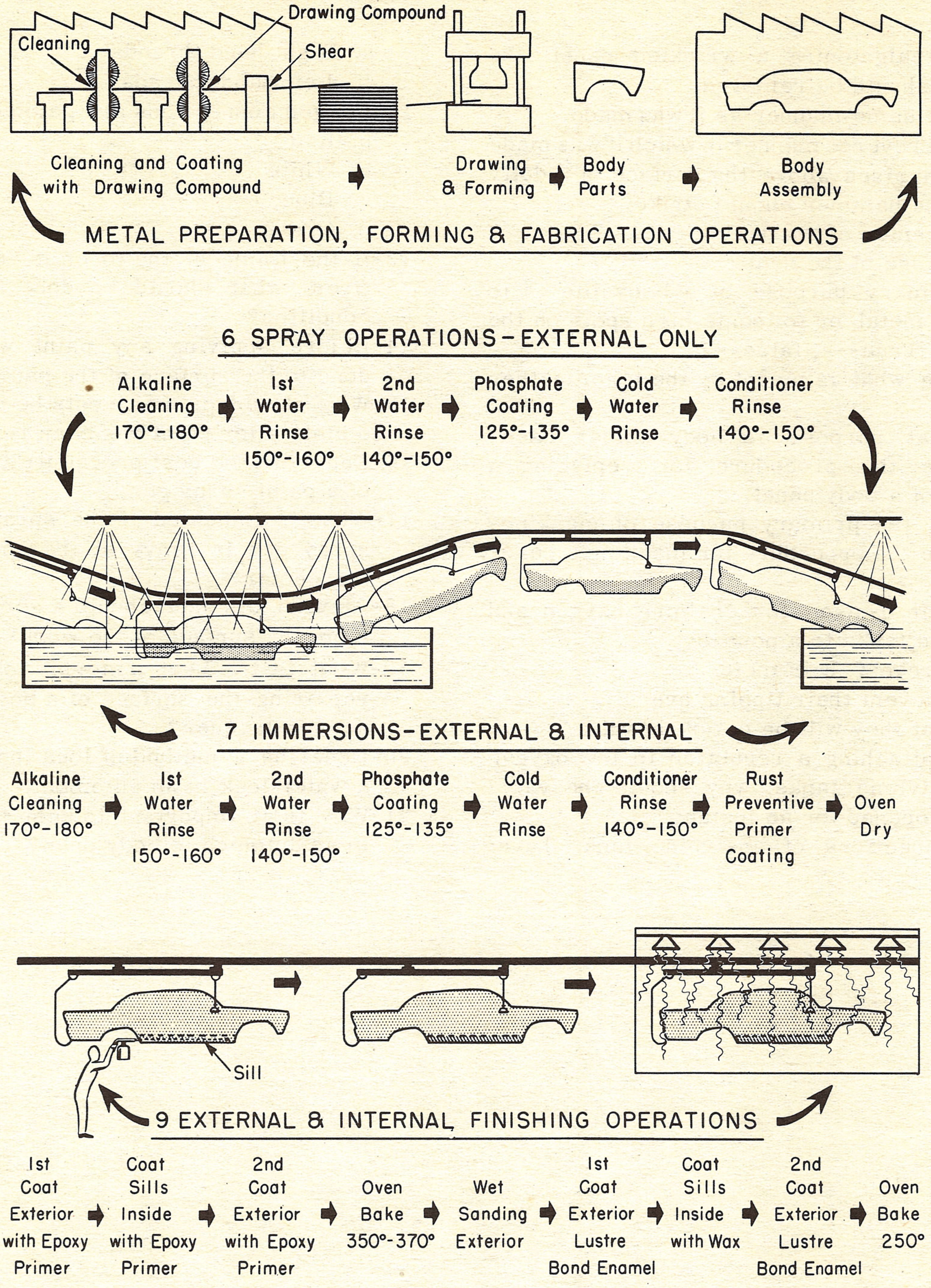
When one of the control switch buttons is actuated, the motor and one of the solenoids are energized simultaneously. The solenoid plunger engages the large gears with a driving gear. The driving gear rotates the large gears which rotate the drive cables and operate both adjusters. When the switch contacts are opened, a spring returns the solenoid plunger to its original position, disengaging the large gears from the driving gears.


#1 — Rear Vertical Solenoid
#2 — Horizontal Solenoid
#3 — Front Vertical Solenoid
Rear Vertical Control Cable — Blue
Front Vertical Control Cable — Yellow
Seat Control Switch
Horizontal Control Cable — Black
Transmission And Solenoid Assembly
1
2
3
Seat Motor
Rear Vertical Control Cable — Blue
Motor Drive Cable
Horizontal Control Cable — Black
Seat Harness Feed Connector
Transmission End Plate
Front Vertical Control Cable — Yellow
Harness To Motor Relay Connector
Harness To Transmission Connector
Dark Green—Rear Edge Vertical Cycle
White—Front Edge Vertical Cycle
Dark Blue—Horizontal Cycle
Seat Ground Wire

50-101. In the six-way seat, movement of the seat is controlled by means of the electric motor, solenoids, gearing and drive cables.

QUIZ - BODY REPAIRING, REFINISHING

1-When straightening a wrinkled panel, the damage should be removed:
   a. In the same manner as it was made
   b. In the reverse manner in which it was made
2-If a dent rises above the surface of a dolly block, the hammer should strike:
   a. The center of the dent
   b. The edge of the dent
3-The primary purpose of a body file is to remove metal or to locate high spots on the surface. True---, false---
4-Describe what is meant by the term feather edging.
5-For what purpose is body solder used?
6-Describe the procedure for replacing a portion of a body panel.
7-What is the primary purpose of masking?
8-Describe the procedure for masking a headlamp.
9-The main reason for chaining oxygen and acetylene tanks to a post is:
   A. To prevent their theft
   b. To prevent their tipping over
   c. So that they will be out of the way
10-Before attaching a regulator to the oxygen and acetylene tanks, why should the valve first be opened for an instant.
11-The connections of acetylene tanks have:
   a. Right hand threads
   b. Left hand threads
12-Oxygen connections are painted:
   a. Red
   b. White
   c. Blue
   d. Green
13-If the flame at the torch is yellow or backfires, what should be done to correct the condition?
14-Before applying any paint what should be done to the surface of the panel?
15-Why should primer coats be applied immediately after paint has been removed?
16-Describe the best procedure for taking care of a paint spray gun.
17-What is indicated if the spray pattern of a spray gun is heavy at the ends and light at the center?
18-At what distance should a spray gun be held from the surface of the work?
19-What is the best material to be used when repairing the surface of a body painted with acrylic lacquer?
20-Describe a method of locating the source of a water leak in an automobile body.
21-Why is it important to keep the drain holes in an automobile body open?


Drawing Compound
Cleaning
Shear
Cleaning and Coating with Drawing Compound
Drawing & Forming
Body Parts
Body Assembly
METAL PREPARATION, FORMING & FABRICATION OPERATIONS
6 SPRAY OPERATIONS-EXTERNAL ONLY
Alkaline Cleaning 170°-180°
1st Water Rinse 150°-160°
2nd Water Rinse 140°-150°
Phosphate Coating 125°-135°
Cold Water Rinse
Conditioner Rinse 140°-150°
7 IMMERSIONS-EXTERNAL & INTERNAL
Alkaline Cleaning 170°-180°
1st Water Rinse 150°-160°
2nd Water Rinse 140°-150°
Phosphate Coating 125°-135°
Cold Water Rinse
Conditioner Rinse 140°-150°
Rust Preventive Primer Coating
Oven Dry
Sill
9 EXTERNAL & INTERNAL FINISHING OPERATIONS
1st Coat Exterior with Epoxy Primer
Coat Sills Inside with Epoxy Primer
2nd Coat Exterior with Epoxy Primer
Oven Bake 350°-370°
Wet Sanding Exterior
1st Coat Exterior Lustre Bond Enamel
Coat Sills Inside with Wax
2nd Coat Exterior Lustre Bond Enamel
Oven Bake 250°

Unibody corrosion protection as offered by Chrysler Corp.

HYDRAULICS AND PNEUMATICS

HYDRAULICS

The study of hydraulics is important and necessary to the automotive mechanic because so many parts of the automotive vehicle and servicing equipment are dependent for their operation on liquids under pressure, and in motion. For example, the conventional braking system used on passenger cars is of the hydraulic type and the modern automatic transmission depends on hydraulics for its operation. In the service field, jacks, lifts and presses are operated hydraulically.

Technically, liquids and gases are considered as fluids, and while they have many characteristics in common, they differ mainly in that liquids change but slightly when they are compressed. In addition they have a free surface. Gases, however are compressible and will fill all parts of the containing vessel.

The complete science of hydraulics includes the manner in which liquids act in tanks and pipes. It includes the laws of floating bodies and the behavior of liquids on submerged surfaces. The subject also treats of the flow of liquids under various conditions and methods of directing this flow to accomplish useful work.

In this text, however, the study will be limited primarily to hydraulics as it is applied in the automotive field.

ADVANTAGES OF HYDRAULIC SYSTEMS

Among the advantages of hydraulic systems are:

a. The elimination of complicated systems of gears, cams and rods.
b. Motion can be transmitted without slack or lost motion.
c. Liquids are not subjected to wear or breakage as in the case with mechanical parts.
d. Hydraulic systems require no lubrication.
e. Applied force can be greatly multiplied and transmitted considerable distances with negligible loss.

PHYSICAL PROPERTIES OF LIQUIDS

Liquids differ from solids in that they do not have a definite form of their own, but conform to the shape of the vessel in which they are contained. Because of the shapelessness of liquids, they can be carried in tubing by gravity or by applying force to them.

In general, liquids may be considered as being incompressible. In fact, a force of 15 lb. on a cubic inch of water will compress it only 1/20,000 and it would take a force of 32 tons to reduce it 10 per cent. When pressure is removed, the liquid being elastic, immediately returns to its original volume.

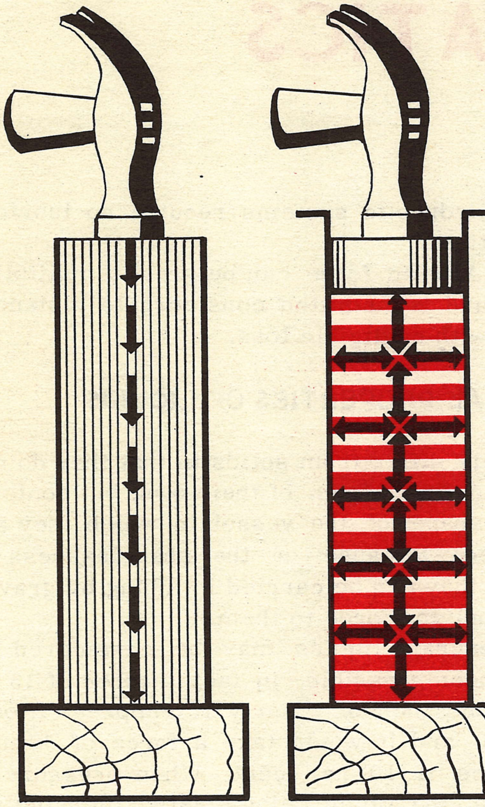
TRANSMISSION OF FORCES

One of the most important characteristics of liquids is that when force is applied to a confined liquid it will be transmitted in ALL directions. This is known as Pascal's principle.

To make this clear, consider a metal bar. Striking it on the end, the force will be transmitted the length of the bar, Fig. 51-1. The more rigid the bar, the less force is lost inside the bar, or will be transmitted at right angles to the direction of the blow.

However, when a force is applied to the end of a confined liquid, also shown in Fig. 51-1, it is transmitted straight through to the other end (the same as in the case of the metal bar) but in addition, the force is transmitted equally and undiminished in every direction --- forwards, backwards, sidewards -- so that the containing vessel is literally filled with pressure.

Furthermore, this pressure is at right angles to the containing surfaces. Pressure of a liquid standing in an open vessel is dependent on the depth of the liquid. This is known as the hydraulic head. Pressure due to the hydraulic head is also dependent on the weight of the liquid. This is known as the density of the liquid, which is the weight in pounds of a cubic inch or cubic foot of the liquid. Water weighs 62.357 lb. per cubic foot or .03612 lb. per cubic inch. Heavy petroleum oil weighs .0317 and light oil .0287 lb. per cu. in.



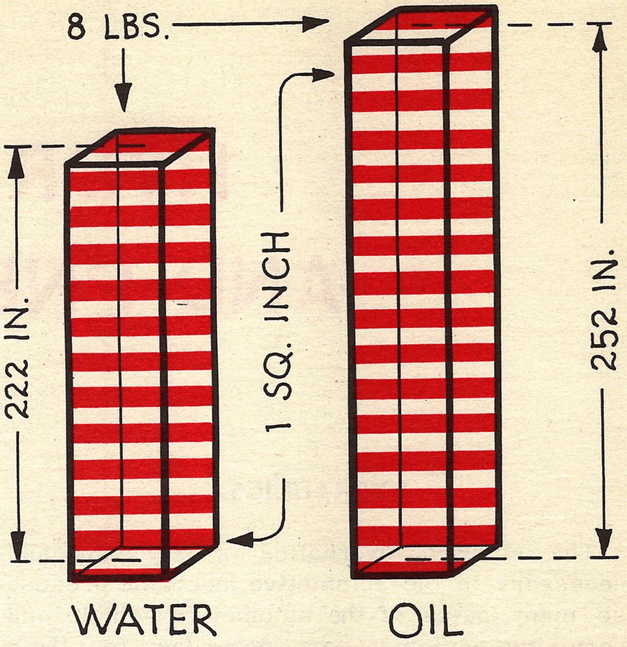
51-1. Illustrating the difference in the action of forces when a solid bar is struck, and when a force is applied to the end of a confined liquid.

In the example illustrated in Fig. 51-2 the water would have to be 222 in. deep to exert a pressure of 8 p.s.i. in the case of heavy oil it would have to be 252 in. as shown in Fig. 51-2.

SPECIFIC GRAVITY

One method of comparing liquids is by their specific gravity, which is the ratio of the weight of a unit volume of that substance (its density) to the weight of 1 cu. in. of water. Since the weight may vary as temperature changes, the measurement is always made at 39.1 deg. F. or 4 deg. C.

The weight of a cubic inch of water is .036 lb. while the weight of a typical hydraulic fluid such as is used in an automotive brake system, is .0357 lb. per cu. in. The specific gravity of the fluid is then obtained by dividing .0357 by .036 which equals 0.99 sp. gr.



51-2. Illustrating the effect of density on pressure. The 222 in. column of water and the 252 column of oil produce the same pressure.

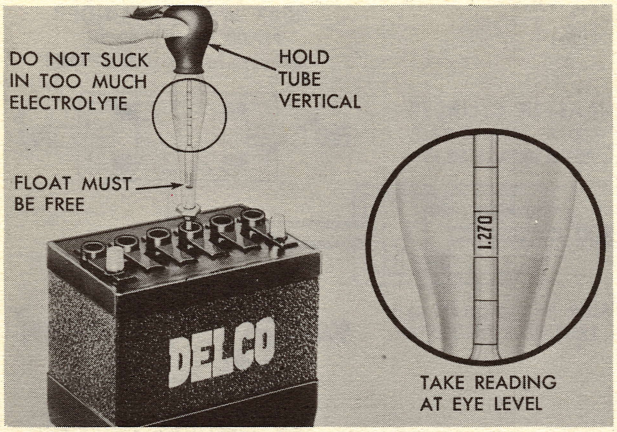
In automotive service work specific gravity is used particularly in the measurement of anti-freeze solutions to determine at what temperature the solution in the system will freeze. It is also used in measuring the state of charge in a starting battery.

HYDROMETERS

To measure the specific gravity of a solution an instrument known as a hydrometer is used. As shown in Fig. 51-3, the hydrometer consists of a glass tube, containing a calibrated float. The fluid to be measured is drawn into the glass tube by means of a rubber suction bulb at one end. Then, the height of the float above the surface of the liquid is a measurement of its specific gravity.

PRESSURE AND FORCE IN HYDRAULIC SYSTEMS

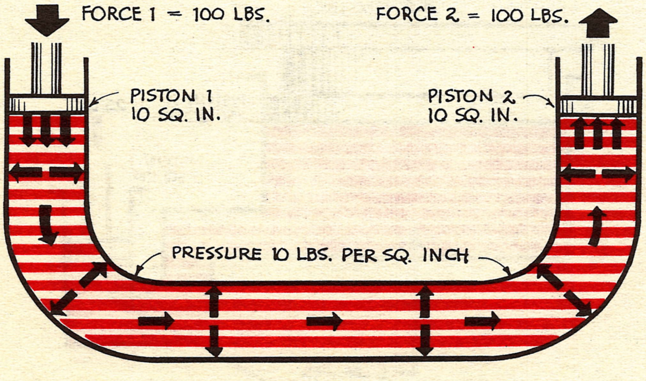
According to Pascal's law, any force applied to a confined liquid is transmitted equally in all directions through the liquid regardless of the shape of the container. In Fig. 51-4, when a force is applied to piston No. 1, a pressure will be created throughout the entire system which will act at right angles to all surfaces with equal strength. Pressure is defined as the force divided by the area over which it is distributed. In the case illustrated in Fig. 51-4, the force applied at piston No. 1 is 100 lb. as the area of the piston is 10 sq. in., then the pressure is 100 divided by 10 or 10 lb. p.s.i.


DO NOT SUCK IN TOO MUCH ELECTROLYTE
HOLD TUBE VERTICAL
FLOAT MUST BE FREE
DELCO
1.270
TAKE READING AT EYE LEVEL

51-3. Example of a hydrometer being used to measure the specific gravity of the acid solution in a storage battery.

This pressure of 10 p.s.i. is exerted over the entire system, the sides of the system as well as piston No. 2, which is at the greatest distance from piston No. 1, where the force is applied. As the vessel containing the fluid is of uniform cross section, and both pistons are the same area, the upward force on piston No. 2, is the same as the force applied to piston No. 1. What has been done is to change the direction of the force from downward at piston No. 1, to upward at piston No. 2.

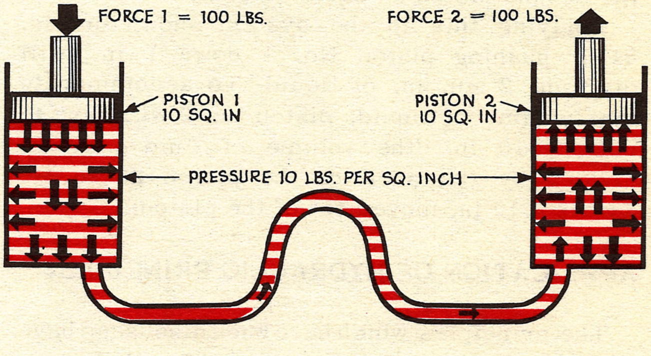
While the system shown in Fig. 51-4 is of uniform cross section, this is not necessary in order that the same force is available at the output side as is applied at the input side. This is true because of Pascal's law. In other words the connection between piston No. 1 and piston No. 2 can be any shape or size. This is made clear in Fig. 51-5, where the connection between the two pistons is a tube of smaller diameter than the pistons.


FORCE 1 = 100 LBS.
FORCE 2 = 100 LBS.
PISTON 1 10 SQ. IN.
PISTON 2 10 SQ. IN.
PRESSURE 10 LBS. PER SQ. INCH

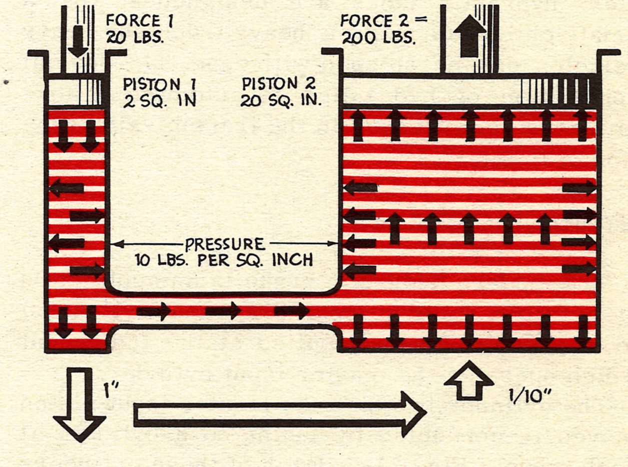
51-4. Force applied to a fluid in a confined system is transmitted equally in all directions throughout the system, regardless of the shape of the system.

MULTIPLYING THE FORCE

In the cases considered so far, there has been no increase in the force as the input piston has been the same size as the output piston. However, if the output piston is made larger in diameter than the input piston, the force will be increased in the same proportions as the areas of the two pistons. For example, in Fig. 51-6, piston 1 (the input piston) has an area of 2 sq. in., while the area of the output piston No. 2, is 20 sq. in. If a force of 20 lb. is applied to piston No. 1, the pressure on the liquid will be 10 p.s.i. (20 lb. divided by 2 sq. in. equals 10 p.s.i.).


FORCE 1 = 100 LBS.
FORCE 2 = 100 LBS.
PISTON 1 10 SQ. IN
PISTON 2 10 SQ. IN
PRESSURE 10 LBS. PER SQ. INCH

51-5. The shape and size of the connecting tube has no affect on the pressures in the cylinders.


FORCE 1 20 LBS.
FORCE 2 = 200 LBS.
PISTON 1 2 SQ. IN
PISTON 2 20 SQ. IN.
PRESSURE 10 LBS. PER SQ. INCH
1"
1/10"

51-6. Forces can be multiplied by making the output piston larger than the input brake.

As this pressure acts equally throughout the system, there will be 10 p.s.i. acting on the piston No. 2, but as its area is 20 sq. in., the total force on that piston will be 200 lb. (20 sq. in. times 10 p.s.i. equals 200 lb.).

A system shown in Fig. 51-6 could also

be used in a reverse manner. In other words it could be used to reduce forces rather than increase them.

MOVEMENT OF LIQUID

In the examples given in Fig. 51-4 and Fig. 51-5, the areas of the pistons were equal. Therefore, if one piston is moved down 1 in., the other piston will be moved upward a corresponding amount. The reason for that is that as the liquid is virtually incompressible, the liquid displaced by the first piston must have some place to go, and it can only move by displacing the second piston an equal amount.

Applying this to the system shown in Fig. 51-6, pushing piston No. 1 down 1 in., will displace 2 cu. in. of liquid. To accommodate that volume of liquid, piston No. 2 will have to move 0.10 in. (the volume of fluid 2 cu. in. divided by the area of the piston 20 sq. in. equals 0.10 in. movement of the piston).

APPLICATION OF HYDRAULIC PRINCIPLES

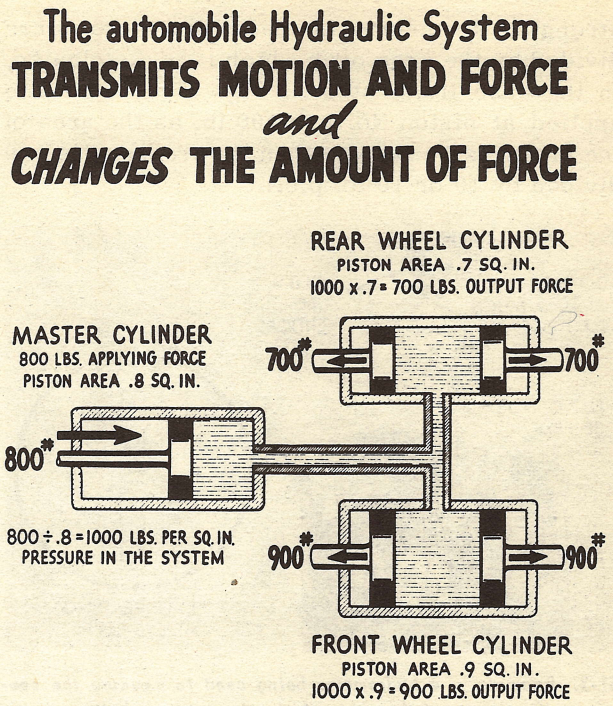
The principles which have been discussed have wide application in the automotive industry. Hydraulic brakes and jacks utilize these principles. By proper application of these principles, hydraulic jacks are designed so that a small child can raise a heavy truck and heavy vehicles can be stopped with ease. The special application of hydraulics to automatic transmissions is discussed in the transmission section of this text.

HYDRAULIC BRAKES

The modern hydraulic brake is an application of multiple outlet pistons (the wheel cylinders) to distribute forces applied at the foot pedal which operates the master input cylinder.

The cylinder in which the master input piston moves is connected by tubing to a cylinder at each wheel, Fig. 51-7. Each of these cylinders contains two opposed pistons, and each piston operates a brake shoe. When force is applied at the brake pedal, pressure is transmitted equally throughout the fluid to each of the wheel cylinders. As a result, all of the wheel cylinders are forced outward, forcing the brake shoes against the brake drums.

When the pressure is removed from the brake pedal, springs on the brake shoes force the shoes back to their normal released position. This movement of the shoes, in turn, forces the pistons inward returning the fluid back to the master cylinder and its reservoir.

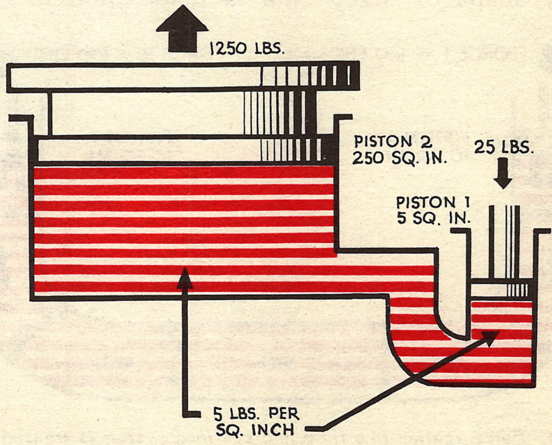

The automobile Hydraulic System
TRANSMITS MOTION AND FORCE
and
CHANGES THE AMOUNT OF FORCE
REAR WHEEL CYLINDER
PISTON AREA .7 SQ. IN.
1000 x .7 = 700 LBS. OUTPUT FORCE
MASTER CYLINDER
800 LBS. APPLYING FORCE
PISTON AREA .8 SQ. IN.
700#
700#
800#
800 ÷ .8 = 1000 LBS. PER SQ. IN.
PRESSURE IN THE SYSTEM
900#
900#
FRONT WHEEL CYLINDER
PISTON AREA .9 SQ. IN.
1000 x .9 = 900 LBS. OUTPUT FORCE

51-7. *Illustrating the principle of the hydraulic brake.*

This description covers the operation of a simple hydraulic brake with all wheel cylinders of the same diameter. In actual practice, smaller pistons are often used to operate the rear wheel brakes, some designs provide individual cylinders for each shoe and in some instances, the wheel cylinders are designed with a large diameter cylinder for operating forward shoes and a smaller piston for operating the rear shoes of a single brake. Such construction is discussed in the chapter on brakes.

HYDRAULIC JACKS

A schematic drawing of the principle used in the operation of hydraulic jacks is shown in


1250 LBS.
PISTON 2
250 SQ. IN.
25 LBS.
PISTON 1
5 SQ. IN.
5 LBS. PER
SQ. INCH

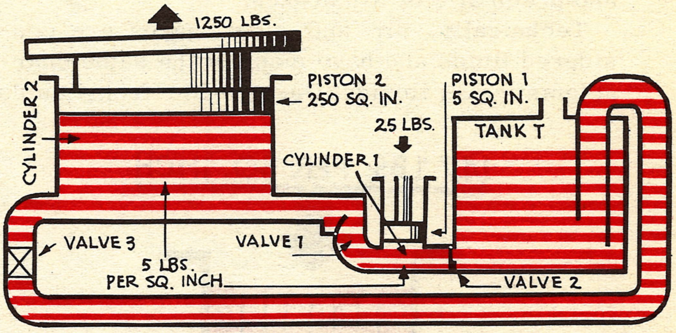
51-8. *Illustrating the principle of the hydraulic jack.*

Fig. 51-8. In the illustration the small piston, where the force is applied, has an area of 5 sq. in. Its cylinder is directly connected to a large cylinder with a piston which has an area of 250 sq. in. This large piston forms the platform which is used to raise the load.

If a force of 25 lb. is applied to the small piston, a pressure of 5 lb. p.s.i. will be produced in the hydraulic fluid. This 5 p.s.i. will act over the entire area of the large piston with its 250 sq. in. surface. The resulting force will be 250 x 5 = 1250 lifting force. In other words, an initial force of only 25 lb. has been transformed into a force capable of lifting more than one half ton.

It must be remembered, however, that while the original force has been multiplied 50 times, the distance traveled is just the opposite. If the small piston is moved 5 in., then 25 cu. in. of liquid will be displaced. Distributing this over 250 sq. in. of the larger piston, the piston will be raised 25 divided by 250 or 0.1 in.

To prevent the weight of the load on the platform from forcing the fluid back through the system, and also to provide ways and means of lowering the load, it is necessary to include various valves in the system, Fig 51-9.



51-9. Schematic drawing of hydraulic jack showing the valving necessary to maintain the load at the desired height, and also to lower the load when desired.

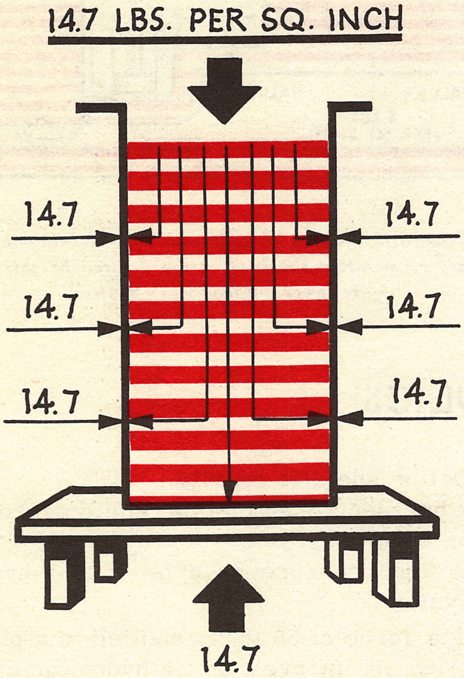
QUIZ - HYDRAULICS

1. Give three examples of the use of hydraulics in the automotive field.
2. Define hydraulics.
3. Name four major advantages of the hydraulic system.
4. State Pascal's law.
5. What is meant by hydraulic head?
6. On what two factors does hydraulic head depend?
7. a. What is the weight of a cu. in. of water?
   b. What is the weight of a cu. in. of hydraulic fluid?
8. Define density of a fluid.
9. Define specific gravity.
10. What piece of automotive equipment depends on specific gravity for its operation?
11. Define pressure as applied to a hydraulic system.
12. If a force of 50 lb. is applied to a piston of 2 sq. in. in area on an hydraulic cylinder what is the pressure?
13. In an hydraulic jack, the input piston has an area of 3 sq. in. and the output piston an area of 300 sq. in. If 30 lb. is applied at the input piston, what is the lifting force at the output piston?

PNEUMATICS

Pneumatics is the study of the mechanical properties of air and other gases, and has many applications in the automotive field. It is particularly important in the study of carburetion and pneumatic or air brakes.

Technically, air and other gases are considered fluids and have many of the same characteristics as liquids. Gases differ from liquids mainly in that they are highly compressible and completely fill any containing vessel. But gases are the same as liquids, in that they conform to the shape of their containers, and pressure in a gas acts equally in all directions.



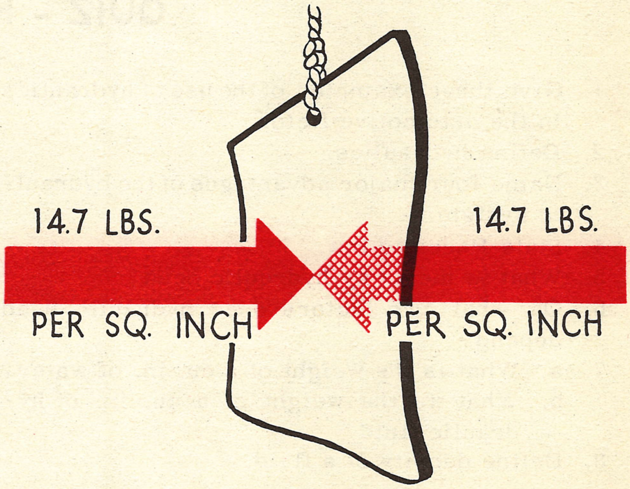
51-10. Atmospheric pressure acting on the surface of gas or liquid is transmitted equally throughout.

Air and any gas has weight, and therefore exerts pressure by virtue of its head; that is, its depth from the upper surface to the lower surface of the gas. Although any small volume of any gas weighs very little, the pressure of air at sea level under standard conditions amounts to 14.7 p.s.i. The pressure or the head is the weight of the air from the surface of the earth extending many miles upward into space.

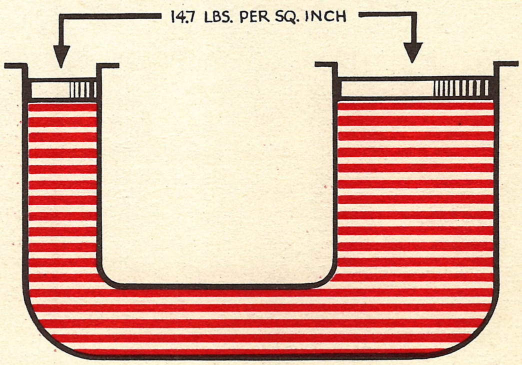
Since air is compressed by its own weight, the same volume of air at sea level will weigh considerably more than on a mountain top. In other words, air becomes less dense as altitude or distance from the earth increases. This is particularly important because of its effect on carburetion. As altitude increases, less air enters the carburetor, consequently the mixture of fuel and air becomes richer. Instruments designed to measure the pressure of the atmosphere are known as barometers. They are used largely in forecasting weather, and in measuring altitudes.

As has been pointed out, gases are compressed by their own weight, and therefore the same volume of air at sea level will weigh considerably more than on top of a mountain. In addition, gases expand as their temperature is increased, so that a volume of gas at high temperature will weigh less than the same volume of gas at low temperature. That is why the efficiency of an automobile decreases as the temperature of the air entering the carburetor increases.

Atmospheric pressures obey Pascal's law in the same manner as liquids. This condition is shown in Fig. 51-10, where atmospheric pressure, acting on the surface of the gas or liquid, is transmitted equally throughout the gas or liquid to the walls of the container, but it is balanced by the pressure on the outer walls of the container. The thinnest of paper, when suspended



51-11. Thin paper will not be torn in spite of the fact that air pressure of 14.7 p.s.i. is pressing on it.



51-12. Atmospheric pressure acting on one piston is balanced by the same pressure acting on the other piston.

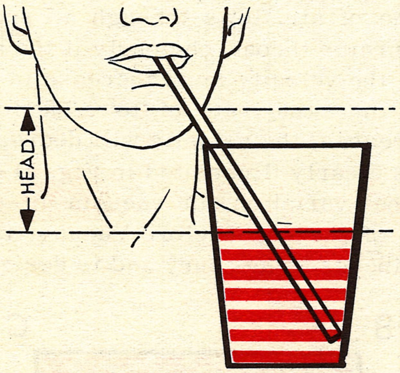
in the atmosphere will not be torn in spite of the fact that air pressure of 14.7 p.s.i. is pressing on it, Fig. 51-11. The reason the paper is not torn is that the pressure is exerted on both sides of the sheet and the pressures are therefore balanced.

In Fig. 51-12, atmospheric pressure acting on one piston is balanced by the same pressure acting on the surface of the other piston. The fact that the two pistons are of different areas makes no difference as the unit pressure, that is the pressure per square inch, is the same on both pistons.

EFFECT OF VACUUM

As pointed out in the preceding paragraph, with equal atmospheric pressure acting on the two surfaces, Fig. 51-12, the liquid will be at the same height in both sides of the U-shape tube. If the pressure on one side of the tube is reduced, there will be a movement of liquid to the side of the reduced pressure.

This can be illustrated by the familiar situation of drinking soda through a straw, Fig. 51-13. When soda is sucked through a straw, the balance of pressures acting on the liquid is disturbed. The pressure within the straw is reduced as the result of suction, and as a result the air pressure (14.7 p.s.i.) acting on the surface of the liquid in the glass, forces the liquid into the straw.

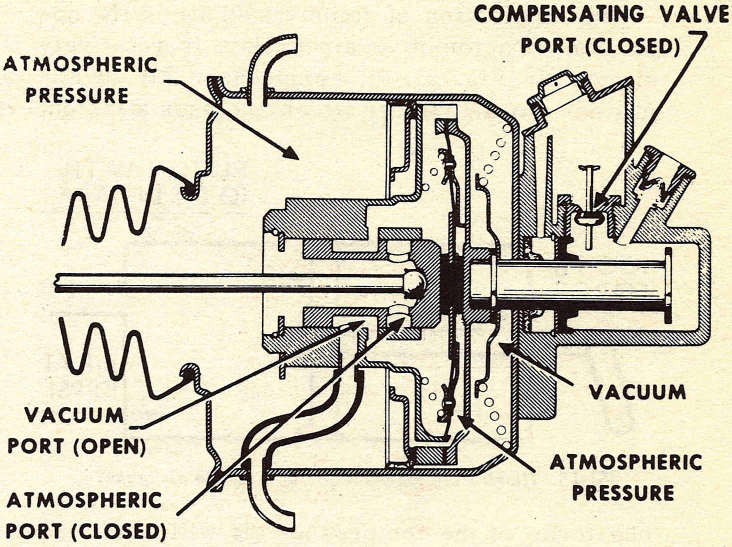


51-13. With air pressure within the straw reduced below that of the atmosphere, air pressure forces the liquid into the straw.

The liquid can be held at any desired level in the straw. This level will always be where the pressure of the head of the liquid, Fig. 51-13, equals the difference between the pressure in the straw, and that on the surface of the liquid.

Sucking on the straw has produced a partial vacuum on the surface of the liquid within the straw. A partial vacuum is actually a pressure that is less than the prevailing atmospheric pressure. Theoretically, the limit of this process would be a condition of zero pressure -- a complete vacuum. In actual practice this has never been attained.

This simple principle, illustrated by sucking soda through a straw is identical with that which is used in the operation of a conventional power brake with which many passenger cars are equipped, Fig. 51-14. Vacuum from the intake manifold is connected to one side of a cylinder. Atmospheric pressure on the other side causes a piston to move toward the vacuum side, and this motion is used to apply the brake.



51-14. Typical power brake unit. There is atmospheric pressure on one side of the piston and vacuum on the other.

COMPRESSED AIR

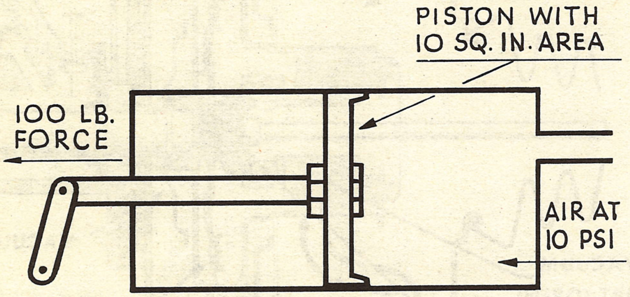
Compressed air is air which has been forced into a smaller space than which it would ordinarily occupy in its free or atmospheric state. In the automotive field, compressed air has many uses. In addition to inflating tires, it is used for such purposes as spraying paint, blowing dirt and other foreign matter from parts, operating brakes on heavy trucks, and to operate impact wrenches.

As pointed out previously, normal air (due to the weight of air above it) has a pressure of 14.7 p.s.i. However, when speaking of compressed air, its initial pressure of 14.7 p.s.i. is ignored, and the pressure of the compressed air is given as the amount of pressure above atmospheric. In other words, a gauge for measuring the pressure of compressed air registers zero when connected only to the atmosphere.

By providing suitable piping, compressed air will "flow" in much the same manner as liquids flow along connecting pipes. For example, if two reservoirs are connected, one containing air under pressure, and the other air at atmospheric pressure, air will flow from the reservoir of higher pressure to that of lower pressure. This flow will continue until both reservoirs are at the same pressure.

AIR BRAKES

The application of compressed air in the operation of automotive air brakes is relatively simple. In Fig. 51-15, compressed air is admitted into a cylinder which encloses a piston.



51-15. Illustrating the principle of a simple air brake.

The force of the compressed air will cause the piston to move until it encounters a resistance equal to the force developed by the compressed air. As the piston in Fig. 51-15 has an area of 10 sq. in., and the compressed air a pressure of 10 p.s.i., the total force developed will be 10 x 10 or 100 lb. This is similar to the effect of hydraulic power illustrated in Fig. 51-4 and Fig. 51-6.

It must be remembered that the quantity of air acting on the piston does not affect the force developed. The only factors involved are the air pressure, and the area of the piston on which the air pressure is acting.

PRINCIPLE OF THE SYPHON

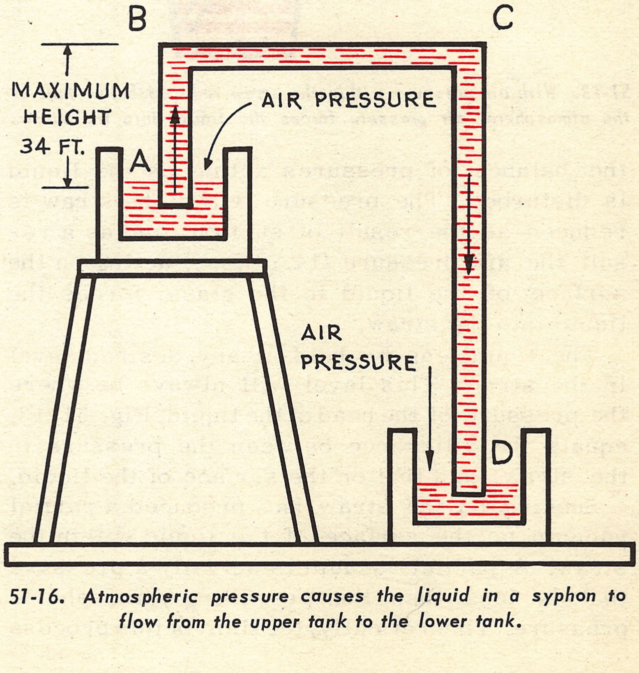
Normal air pressure (or the pressure of the atmosphere) is used to do many kinds of work. For example, the syphon drains tanks by means of atmospheric pressure. In a syphon, a tube or pipe is connected to two tanks, one higher than the other, as shown in Fig. 51-16. Once the connecting tube has been filled with liquid, it will continue to flow to the lower tank until the level of the liquid is the same in both tanks or until the upper tank is empty. The force that causes the liquid to flow is the pressure of the atmosphere. This pressure forces the liquid up the short arm of the syphon (AB). Theoretically, the liquid can be raised a height of 34 ft. if the liquid is water. Denser liquids cannot be raised as far. However, at high altitudes, where air pressure is less than at sea level, the liquid could be raised a shorter distance.

The action of the syphon is of interest. The force of the atmosphere tending to push the liquid up the short arm of the syphon is opposed by the downward pressure due to the weight of the liquid, as in AB Fig. 51-16. Similarly, the atmospheric pressure tends to drive the liquid up the long arm CD, but is resisted by the weight of the liquid. As the weight of the liquid in CD is greater than that in AB, the atmospheric pressure meets greater resistance in pushing the liquid up CD than it meets in pushing it in the opposite direction. The liquid will therefore flow up the arm AB, and continue until it reaches the lower reservoir.

VENTURI TUBE

Because of its importance in carburetion, it is necessary to study the action of the venturi tube. A venturi tube is a tube with a restricted section, Fig. 51-17. When a liquid or air is passed through such a tube, the speed of flow is increased at the area of restriction and the fluid pressure is decreased. Since the same amount or volume of air flows through all sections of the carburetor throat, obviously if the area decreases, the velocity must increase in order to maintain the same rate of flow. Then when the area increases, the velocity will decrease.

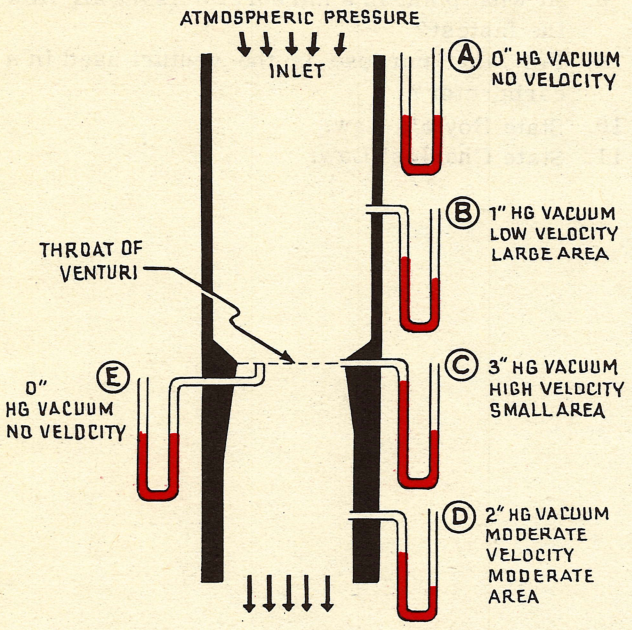
This is clearly illustrated in Fig. 51-17. This shows the variation in vacuum in different sections of the carburetor. Vacuum is measured in inches of mercury and is designated as



51-16. Atmospheric pressure causes the liquid in a syphon to flow from the upper tank to the lower tank.

inches HG, (the initials used in the chemical symbol representing mercury). Note at the point of maximum restriction that the vacuum and the velocity of air flow is at a maximum. Also at the air inlet to the carburetor where the air pressure is normal, the vacuum is zero.

The operation of the venturi is used in carburetors to maintain the correct air-fuel ratio throughout the range of speeds and loads of the engine.


ATMOSPHERIC PRESSURE
INLET
Ⓐ 0" HG VACUUM NO VELOCITY
Ⓑ 1" HG VACUUM LOW VELOCITY LARGE AREA
THROAT OF VENTURI
Ⓒ 3" HG VACUUM HIGH VELOCITY SMALL AREA
Ⓔ 0" HG VACUUM NO VELOCITY
Ⓓ 2" HG VACUUM MODERATE VELOCITY MODERATE AREA

51-17. *In the throat of the venturi moving air will have the greatest velocity and maximum vacuum will exist as shown at C. However, if air flow is stopped, the vacuum becomes zero.*

BOYLE'S LAW

An important characteristic of air and other gases is that if the pressure on a gas in a confined space is doubled, the gas will be compressed to half its original volume, provided the temperature remains the same. This is known as Boyle's law after its discoverer. The law is normally given as follows: If the temperature of a confined gas is kept constant, its volume will vary inversely with its pressure.

This may be expressed as follows:

$$P'V' = PV$$

where P and V represent the pressure and volume of a gas before compression, and P' and V' the pressure and volume after compression. For example, if the pressure of a quantity of gas is 50 p.s.i., and it occupies 10 cu. ft., this air is then compressed until it exerts a pressure of 75 p.s.i. Temperature remains constant. What is the volume of the gas after compression?

$$\frac{V}{V'} = \frac{P'}{P}$$

$$\frac{75}{50} = \frac{10}{P}$$

$$75P = 500$$

$$P = 6.66 \text{ cu. ft.}$$

CHARLES LAW

Another important law relating to the behavior of gases under different conditions is known as Charles' law which states that under constant pressure, volume of a gas varies directly with the absolute temperature of the gas. The absolute temperature is the temperature in C. degrees plus 273. This law is expressed as follows:

$$\frac{V'}{V_2} = \frac{T'}{T_2}$$

where V' is the volume of a gas when its absolute temperature is T' and V_2 is the volume of the same gas when its absolute temperature is T_2.

Example: To what volume will 110 cu. ft. of gas at 15 deg. C expand if heated at a constant pressure to 55 deg. C.

$$T' = 15^{\circ} + 273 = 288^{\circ} \text{ absolute}$$
$$T_2 = 55^{\circ} + 273 = 328^{\circ} \text{ absolute}$$

$$\frac{110}{V_2} = \frac{288}{328}$$

$$36080 = 288V_2$$
$$V_2 = 125.3 \text{ cu. ft.}$$

QUIZ - PNEUMATICS

1. What is the normal pressure of the atmosphere?
2. What is the major difference between a liquid and a gas?
3. What causes the liquid to rise in a soda straw?
4. In the conventional power or booster brake used on a passenger car, what power is used to assist the car driver to apply the brakes?
5. In a conventional gauge such as is used to measure the pressure in a tank of compressed air, what will the gauge register when the tank is open to the atmosphere?
6. Draw an illustration and explain the principle of a siphon.
7. What is a venturi tube?
8. At what point in a carburetor is the air flow the fastest?
9. For what purpose is the venturi used in a carburetor?
10. State Boyle's Law.
11. State Charles' Law.

GLOSSARY OF AUTOMOTIVE TERMS

AAA: American Automobile Association.

AABM: Association of American Battery Manufacturers, Inc.

ABRASION: Wearing or rubbing away, such as sandpapering wood.

ACCELERATOR: A foot operated pedal for regulating speed of the engine.

ACCUMULATOR: The English term for a storage battery.

ACETYLENE OR OXY-ACETYLENE WELDING: The utilization of an acetylene flame to provide heat to bring metal to the fusion or melting point when uniting it.

ACKERMAN PRINCIPLE: The design whereby the wheel spindles are mounted on the axle ends so as to permit the spindles to be turned at an angle to the axle for steering purposes.

ACTIVE MATERIAL: In a storage battery, this refers to the peroxide of lead (brown) in the positive plates and metallic lead (gray) in the negative plates upon which the sulphuric acid acts.

ADAPTOR CARBURETOR: A device attached to the gasoline carburetor when an internal combustion engine is to be run either on gasoline or on liquefied petroleum gas.

ADDITIVE: As used with reference to automotive oils, a material added to the oil to give it certain properties. For example, a material added to engine oil to lessen its tendency to congeal or thicken at low temperature.

AEA: Automotive Electric Association.

AERA: Automotive Engine Rebuilders Association.

AFC: American Finance Conference.

AIR: A gas containing approximately 4/5 nitrogen, 1/5 oxygen and some carbonic gas.

AIR CLEANER: A device for filtering, cleaning, and removing dust from the air admitted to a unit, such as an engine or air compressor.

AIR FUEL RATIO: The ratio by weight of the fuel as compared to the air of the carburetor mixture.

AIR GAP: The space between spark plug electrodes, motor and generator armatures, field shoes, etc.

AIR HORN: The air inlet of the carburetor to which the air cleaner is ordinarily attached.

AIR-LOCK: A bubble of air trapped in a fluid circuit which interferes with normal circulation of the fluid.

ALAM: The Association of Licensed Automobile Manufacturers.

ALIGNMENT: An adjustment to a line or to bring into a line.

ALLEN WRENCH: A hexagonal wrench which fits into a recessed hexagonal hole. Ordinarily used in set screws.

ALLOY: A mixture of different metals such as solder which is an alloy consisting of lead and tin.

ALTERNATING CURRENT: An electrical current alternating back and forth in direction of flow.

ALTERNATOR: Alternating current generator used for automotive purposes. Alternating current is changed to direct current by using a rectifier.

ALUMINUM: A metal noted for its lightness and often alloyed with small quantities of other metals for automotive use.

AMA: Automobile Manufacturers Association.

AMMETER: An instrument for measuring the flow of an electrical current.

AMPERE: The unit of measurement for the flow of electric current.

AMPERE-HOUR CAPACITY: A term used to indicate the capacity of a storage battery. For example, the delivery of a certain number of amperes for a certain number of hours.

ANNEALING: A process of softening metal. For example, the heating and slow cooling of a piece of iron.

ANNULAR BALL BEARING: A ball bearing with a non-adjustable inner and outer race or races.

ANODE: A positive pole of an electrical current.

ANTI-CLOCKWISE ROTATION: Rotating the opposite direction of the hands on a clock. The same as counter-clockwise rotation.

ANTI-FREEZE: A material such as alcohol, glycerin, etc., added to water to lower its freezing point.

ANTI-FRICTION BEARING: A bearing constructed with balls, rollers or the like between the journal and the bearing surface to provide rolling instead of sliding friction.

APERTURE: An opening, hole or port.

API: American Petroleum Institute.

APMA: Automotive Parts Manufacturers Association.

ARC WELDING: A method of utilizing the heat of an electric current jumping an air gap to provide heat for welding metal.

ARMATURE: That part of an electrical machine which includes the main current-carrying winding. In automotive use it is usually the core which rotates within the pole shoes which are surrounded by the field coils. See Electrical Section.

ARTICULATED MOUNTING: A term used in brake shoe installations where the brake shoes are connected by links and the links anchored so as to provide a double hinging action of the shoes.

ASBESTOS: A natural fibrous mineral with great heat resisting ability.

ASME: American Society of Mechanical Engineers.

ATA: American Trucking Association.

ATMOSPHERIC PRESSURE: The weight of the air at sea level; about 14.7 lbs. per square inch; less at higher altitudes.

AUTOMATIC STEERING EFFECT: The inbuilt tendency of an automobile to resume travel in a straight line when released from a turn.

AXLE: The shaft or shafts of a vehicle upon which the wheels are mounted.

B & S GAUGE: Brown and Sharpe gauge which is a standard measure of wire size. The smaller the number, the larger the wire.

BACK-FIRE: Ignition of the mixture in the intake manifold by flame from the cylinder such as might occur from a leaking inlet valve.

BACKLASH: The clearance or "play" between two parts, such as meshed gears.

BACK-PRESSURE: A resistance to free flow, such as a restriction in the exhaust line.

BAFFLE OR BAFFLE PLATE: An obstruction for checking or deflecting the flow of gases or sound.

BALK RING: A friction regulated pawl or plunger used to facilitate engagement of gears.

BALL BEARING: An anti-friction bearing consisting of a hardened inner and outer race with hardened steel balls interposed between the two races. Called ball runners in England.

BATTERY: As used with reference to an automobile, any number of complete electrical cells assembled in one housing or case.

B.D.C.: Bottom dead center.

BEARING: A part in which a journal, pivot or the like turns or moves.

BELL HOUSING: The housing surrounding the flywheel and the clutch or torque converter of an automobile.

BENDIX GEAR OR BENDIX DRIVE: A gear mounted on a screw shaft attached to the starting motor armature which automatically engages and disengages the electric starting motor.

BENZOL: A by-product of the manufacture of coke sometimes used as an engine fuel.

BEZEL: The groove in which a transparent instrument cover is placed.

B.H.P. (Brake Horsepower): A measurement of the power developed by an engine in actual operation.

BLOW-BY: A leakage or loss of pressure often used with reference to leakage of compression past the piston ring between the piston and the cylinder.

BOILING POINT: The temperature at atmospheric pressure at which bubbles or vapors rise to the surface and escape.

BONDED LINING: A method of cementing brake linings to shoes or bands which eliminates the necessity of rivets.

BONNET: English name for hood.

BOOSTER: Often used with reference to a mechanical or hydraulic device attached to brake or steering systems to add to the muscle power applied by the operator.

BORE: The diameter of a hole, such as a cylinder; also to enlarge a hole as distinguished from making a hole with a drill.

BORING BAR: A stiff bar equipped with multiple cutting bits which is used to bore a series of bearings or journals in proper alignment with each other.

BOSS: An extension or strengthened section, such as the projections within a piston which support the piston pin or piston pin bushings.

BOTTLED GAS: Liquefied petroleum gas compressed and contained in portable cylinders.

BRAKE ANCHOR: The pivot on the brake backing plate against which the shoe bears.

BRAKE BAND: A band, surrounding a brake drum, to which the lining is attached.

BRAKE BLEEDING: The procedure for removing air from the lines of a hydraulic system.

BRAKE CYLINDER: A cylinder containing a movable piston which is actuated by hydraulic pressure to move the brake shoes against the braking surface of the drum or disk.

BRAKE DISK: A plate or disk attached to the driveshaft or wheel against which the brake lining is forced to retard the vehicle.

BRAKE DRUM: A metal cylinder attached to the wheel and surrounding the shoe and lining.

BRAKE "FADE": A condition wherein repeated severe applications of the brakes cause expansion of the brake drum or loss of frictional ability or both, which results in impaired braking ability.

BRAKE FLUID: A compounded fluid for use in hydraulic brake systems which must meet exacting conditions. It should be impervious to heat, freezing, thickening, bubbling, etc.

BRAKE FLUSHING: A procedure for removing the fluid from a brake system and washing out any sediment contained therein.

BRAKE LINING: A material having a suitable coefficient of friction which is attached to the brake shoe and which contacts the brake drum to retard the vehicle.

BRAKE SHOE: The carrier to which the brake lining is attached and which is used to force the lining in contact with the brake drum.

BRAKE SHOE HEEL: The end of the brake shoe nearest the anchor pin.

BRAKE SHOE TOE: The end of the brake shoe opposite the anchor pin.

BRAZE: To join two pieces of metal with the use of a comparatively high melting point material. An example is to join two pieces of steel by using brass or bronze as a solder.

BREAKER ARM: The movable part of a pair of contact points in an electrical distributor or magneto.

BREAKER POINT: Also called contact points. Two separable points usually faced with silver, platinum or tungsten which interrupt the primary circuit in the distributor or magneto for the purpose of inducing a high tension current in the ignition system.

BREAK-IN: The process of wearing in to a desirable fit between the surfaces of two new or reconditioned parts.

BRINELL HARDNESS: A scale for designating the degree of hardness possessed by a substance.

BROACH: To finish the surface of metal by pushing or pulling a multiple edge cutting tool over or through it.

BRUSHES: The bars of carbon or other conducting material which contact the commutator of an electric motor or generator.

B.T.U. (British Thermal Unit): A measurement of the amount of heat required to raise the temperature of 1 lb. of water, 1 degree, Fahrenheit.

BUCKLED PLATES: Battery plates that have been bent or warped out of a flat plane.

BURNISH: To smooth or polish by the use of a sliding tool under pressure.

BUSHING: A removable liner for a bearing. Called a bush in England.

BUTANE: A petroleum hydrocarbon compound which has a boiling point of about 32 degs. F. which is used as engine fuel. Loosely referred to as Liquefied Petroleum Gas and often combined with Propane.

BY-PASS: An alternate path for a flowing substance.

CALIBRATE: To determine or adjust the graduation or scale of any instrument giving quantitative measurements.

CALIPERS (Inside and Outside): An adjustable tool for determining the inside or outside diameter by contact and retaining the dimension for measurement or comparison.

CALORIFIC VALUE: A measure of the heating value of fuel.

CALORIMETER: An instrument to measure the amount of heat given off by a substance when burned.

CALORY: The metric measurement of the amount of heat required to raise 1 gram of water from zero degrees to 1 degree Centigrade.

CAM OR BREAKER CAM: The multi-lobed cam rotating in the ignition distributor which interrupts the primary circuit to induce a high tension spark for ignition.

CAM ANGLE: Also known as dwell period. Referring to an ignition distributor, the number of degrees of rotation of the ignition distributor shaft during which the contact points are closed.

CAMBER: As used on automobiles, the angle sidewise from vertical formed by the center of the wheel with the road. See Wheel Alignment Section.

CAM GROUND PISTON: A piston ground to a slightly oval shape which under the heat of operation becomes round.

CAMSHAFT: The shaft containing lobes or cams to operate the engine valves.

CAPE CHISEL: A metal cutting chisel shaped to cut or work in channels or grooves.

CARBON: A common non-metallic element which is an excellent conductor of electricity. It also forms in the combustion chamber of an engine during the burning of fuel and lubricating oil.

CARBON DIOXIDE: Compressed into solid form, this material is known as "dry ice" and remains at a temperature of -109 degs., F. It goes directly from a solid to a vapor state.

CARBON MONOXIDE: Gas formed by incomplete combustion. Colorless, odorless, very poisonous.

CARBONIZE: The process of carbon formation within an engine, such as on the spark plugs and within the combustion chamber.

CARBURETOR: A device for automatically mixing fuel in the proper proportion with air to produce a combustible gas.

CARBURETOR "ICING": A term used to describe the formation of ice on a carburetor throttle plate during the prevalence of certain atmospheric conditions.

CARDAN JOINT: A universal joint with corresponding yokes at a right angle with each other.

CASE-HARDEN: To harden the surface of steel.

CASING: English name for housing.

CASING HEAD GASOLINE: A term used to describe the lighter parts of petroleum products which were obtained as a natural gasoline by condensing natural gas from an oil well.

CASTELLATE: Formed to resemble a castle battlement as in a castellated nut.

CASTER: As used on automobiles, the inclination from vertical fore and aft of the kingpin with the road. See wheel alignment section.

CATHODE: The negative pole of an electric current.

CELL: An electrical cell is the unit of a battery containing a group of positive and negative plates along with electrolyte.

CELL CONNECTOR: The lead bar or link connecting the pole of one cell to the pole of another.

CELLULOID: A compound of gun cotton and camphor which is flexible and transparent.

CENTER OF GRAVITY: The point at which a mass of matter balances. For example, the center of gravity of a wheel is the center of the wheel hub.

CENTIGRADE: A measurement of temperature used principally in foreign countries, zero on the Centigrade scale being 32 degs. on the Fahrenheit scale.

CENTRIFUGAL FORCE: A force which tends to move a body away from its center of rotation. An example is supplied by whirling a weight attached to a string.

CENTRIFUSE BRAKE DRUMS: In order to combine the strength of a steel drum with the desirable friction characteristics of cast iron, a lining of cast iron is sprayed on the inside of a steel drum. Both metals are handled while hot to encourage the fusing of the two metals.

CHAMFER: A bevel or taper at the edge of a hole.

CHARGE (or Recharge): Passing an electrical current through a battery to restore it to activity.

CHASE: To straighten up or repair damaged threads.

CHASSIS: A French word meaning the framework of a vehicle. It is pronounced "shas-sy" and is applied to an automobile assembly without a body and fenders.

CHASSIS DYNAMOMETER: A machine for measuring the power delivered to the drive wheels of a vehicle.

CHECK-VALVE: A gate or valve which allows passage of gas or fluid in one direction only.

CHEMICAL COMPOUND: The combination of two or more chemical elements which can be a gas, a liquid or a solid.

CHEMICAL ELEMENT: Gaseous, liquid or solid matter which cannot be divided into simpler form.

CHILLED IRON: Cast iron on which the surface has been hardened.

CHIP: To cut with a chisel.

CHOKE: A reduced passage, such as a valve placed in a carburetor air inlet to restrict the volume of air admitted.

CHROMIUM STEEL: An alloy of steel with a small amount of chromium to produce a metal which is highly resistant to oxidation and corrosion.

CIRCUIT: The path of electrical current, fluids or gases. Examples: for electricity, a wire; for fluids and gases, a pipe.

CIRCUIT BREAKER: A device for interrupting an electrical circuit; often automatic and may be known as "contact breaker," "interrupter," "cut-out" or "relay."

CLEARANCE: The space allowed between two parts, such as between a journal and a bearing.

CLOCKWISE ROTATION: Rotation in the same direction as the hands of a clock.

CLUTCH: A device for connecting and disconnecting the engine from the transmission or for a similar purpose in other units.

COEFFICIENT OF FRICTION: A measurement of the amount of friction developed between two surfaces pressed together and moved one on the other.

"COLD" MANIFOLD: An intake manifold to which the exhaust gas is not applied for heating purposes.

COMBUSTION: The process of burning.

COMBUSTION SPACE OR CHAMBER: In automobile engines, the volume of the cylinder above the piston with the piston on top center.

COMMUTATOR: A ring of adjacent copper bars insulated from each other to which the wires of the armature or winding are attached.

COMPENSATING PORT: An opening in a brake master cylinder to permit fluid return to the reservoir.

COMPOUND: A mixture of two or more ingredients.

COMPOUND WINDING: Two electric windings, one in series and the other in shunt or parallel with other electric units or equipment. When applied to electric motors or generators, one winding is shunted across the armature while the other is in series with the armature. See Electrical Section.

COMPRESSION: The reduction in volume or the "squeezing" of a gas. As applied to metal, such as a coil spring, compression is the opposite of tension.

COMPRESSION RATIO: The volume of the combustion chamber at the end of the compression stroke as compared to the volume of the cylinder and chamber with the piston on bottom center. See Engine Section.

CONCENTRIC: Two or more circles, having a common center.

CONDENSATION: The process of a vapor becoming a liquid; the reverse of evaporation.

CONDENSER: A device for turning vapor into liquid form if applied to gas. If applied to an electric circuit, the condenser is a device for temporarily collecting and storing a surge of electrical current for later discharge.

CONDUCTOR: A material along or through which electricity will flow with slight resistance; silver, copper and carbon are good conductors.

CONNECTING ROD: Rod that connects the piston to the crankshaft.

CONSTANT MESH TRANSMISSION: An arrangement of gearing wherein the gears remain constantly in mesh instead of being slid into and out of engagement with one another. See Transmission Section.

CONTACT BREAKER: A device for interrupting an electrical circuit; often automatic and may be known as "circuit breaker," "interrupter," "cut-out" or "relay."

CONTACT POINTS: Also called breaker points. Two separable points usually faced with silver, platinum or tungsten which interrupt the primary circuit in the distributor or magneto for the purpose of inducing a high tension current in the ignition system.

CONTRACTION: A reduction in mass or dimension; the opposite of expansion.

CONVECTION: A transfer of heat by circulating heated air.

CONVERTER: As used in connection with liquefied petroleum gas, it is a device which converts or changes L.P.G. from liquid to vapor state for use in the engine.

CORRODE: To eat away gradually as if by gnawing, especially by chemical action, such as rust.

COUNTERBORE: To enlarge a hole to a given depth.

COUNTER-CLOCKWISE ROTATION: Rotating the opposite direction of the hands on a clock. The same as anti-clockwise rotation.

COUNTERSINK: To cut or form a depression to allow the head of a screw to go below the surface.

COUPLING: A connecting means for transferring movement from one part to another; may be mechanical, hydraulic or electrical.

COWL: That portion of the body between the engine compartment and the driver which ordinarily contains the instruments used by the operator.

CRANKCASE: The housing within which the crankshaft and many other parts of the engine operate.

CRANKCASE DILUTION: Under certain conditions of operation, unburned portions of the fuel find their way past the piston rings into the crankcase and oil reservoir where they dilute or "thin" the engine lubricating oil.

CRANKSHAFT: The main shaft of an engine which in conjunction with the connecting rods changes the reciprocating motion of the pistons into rotary motion.

CRANKSHAFT COUNTER-BALANCE: A series of weights attached to or forged integrally with the crankshaft so placed as to offset the reciprocating weight of each piston and rod assembly.

CRUDE OIL: Liquid oil as it comes from the ground.

CU. IN.: Cubic Inch.

CURRENT: As used in automobiles, the flow of electricity.

CUT-OUT (Electric): A device for interrupting an electrical circuit; often automatic and may be known as "circuit breaker," "interrupter," Contact breaker," or "relay."

CUT-OUT (Muffler): A valve which can be used to divert the exhaust gases directly to the atmosphere instead of through the muffler.

CYLINDER: A round hole having some depth bored to receive a piston; also sometimes referred to as "bore" or "barrel."

CYLINDER BLOCK: The largest single part of an engine. The basic or main mass of metal in which the cylinders are bored or placed.

CYLINDER HEAD: A detachable portion of an engine fastened securely to the cylinder block which contains all or a portion of the combustion chamber.

CYLINDER SLEEVE: A liner or tube interposed between the piston and the cylinder wall or cylinder block to provide a readily renewable wearing surface for the cylinder.

DASH: Also known as fire wall. A partition between the engine and the operator.

DASH POT: A device consisting of a piston and cylinder with a restricted opening used to slow down or delay the operation of some moving part.

DEAD CENTER: The extreme upper or lower position of the crankshaft throw at which the piston is not moving in either direction.

DEAD REAR AXLE: A rear axle that does not turn. An example of this is a chain drive to the rear wheels.

DEBAR: English term for prevent.

DEGREE: Abbreviated deg. or indicated by a small "o" placed alongside of a figure; may be used to designate temperature readings or may be used to designate angularity, one degree being 1/360 part of a circle.

DEMAGNETIZE: To remove the magnetization of a pole which has previously been magnetized.

DEMOUNTABLE RIM: A rim for a tire that is readily removable from the wheel proper.

DE-MISTER: English term for defroster.

DENATURED ALCOHOL: Ethyl alcohol to which a denaturant has been added to make it unfit as a beverage.

DENSITY: Compactness; relative mass of matter in a given volume.

DEPOLARIZE: To remove polarity, such as to demagnetize a permanent magnet.

DETERGENT: A compound of a soap-like nature used in engine oil to remove engine deposits and hold them in suspension in the oil.

DETONATION: As used in an automobile, indicates a too rapid burning or explosion of the mixture in the engine cylinders. It becomes audible through a vibration of the combustion chamber walls and is something confused with a "ping" or spark knock. Also see Engine Section.

DIAGNOSIS: In automotive service, refers to the use of instruments to determine the action or behavior of automobile parts in order to locate the seat or cause of improper function.

DIAL GAUGE: A type of micrometer wherein the readings are indicated on a dial rather than on a thimble as in a micrometer.

DIAPHRAGM: A flexible partition or wall separating two cavities.

DIE: One of a pair of hardened metal blocks for forming metal into a desired shape or a thread die for cutting external threads.

DIE CASTING: An accurate and smooth casting made by pouring molten metal or composition into a metal mold or die under pressure.

DIESEL ENGINE: Named after its developer, Dr. Rudolph Diesel, the engine ignites the fuel in the cylinder from the heat generated by compression. The fuel is an oil rather than gasoline and no spark plug or carburetor is required. See Engine Section.

DIFFERENTIAL GEAR: In an automobile the gear system which permits one drive wheel to turn faster than the other. See Rear Axle Section.

DILUTION: See Crankcase Dilution.

DIRECT CURRENT: Electric current which flows continuously in one direction. An example is a storage battery.

DIRECT DRIVE: In automobile transmissions, refers to direct engagement between the engine and driveshaft where the engine crankshaft and the driveshaft turn at the same r.p.m.

DISCHARGE: With reference to a battery, the flow of electric current from the battery; the opposite of charge.

DISPLACEMENT: See Piston Displacement.

DISTORTION: A warpage or change in form from the original shape.

DISTRIBUTORS: A valve often rotary in design which conducts a vapor or fluid to a number of outlets. An example is found in Diesel engine oil distributors. See Diesel Engine Section. For electrical distributors, see Ignition Distributors.

DOG CLUTCH: Mating collars or flanges with projecting lugs or fingers which interlock when engaged.

DOUBLE REDUCTION AXLE: A drive axle construction in which two sets of reduction gears are used for extreme reduction of gear ratio.

DOWEL PIN: A pin inserted in matching holes in two parts to maintain those parts in fixed relation one to the other.

DOWN-DRAFT: Used to describe a carburetor type wherein the mixture flows downward to the engine.

DRAG LINK: The connecting rod or link between the steering gear Pitman arm and the wheel steering spindles.

DRAW: To form by a stretching process or to soften hard metal.

DRAW-FILING: A method of filing wherein the file is drawn across the work while held at a right angle to the length of the file.

DRILL: A tool for making a hole or to sink a hole with a pointed cutting tool rotated under pressure.

DRIVE-FIT: Also known as a force-fit or press-fit. This term is used when the shaft is slightly larger than the hole and must be forced in place.

DRIVE LINE: In automobiles, the universal joints, driveshaft and other parts connecting the transmission with the driving axles.

DROP FORGING: A piece of steel shaped between dies while hot.

DRY BATTERIES: Also called dry cell. A complete battery unit which does not contain liquid electrolyte.

DUAL-FUEL ENGINE: An engine equipped to operate on two different fuels, such as gasoline and L.P.G.

DUAL REDUCTION AXLE: A drive axle construction with two sets of pinions and gears, either of which can be used.

DWELL PERIOD: Also known as cam angle.

DYNAMO: A generator of electricity. See Generator.

DYNAMOMETER: A machine for measuring the actual power produced by an internal combustion engine.

EARTH: English term for ground.

EARTH CONNECTION: This term is sometimes used to designate a "ground" in the electrical system. See Ground.

ECCENTRIC: One circle within another circle wherein both circles do not have the same center. An example of this is a cam on a camshaft.

ECONOMIZER: A device installed in a carburetor to control the amount of fuel used under certain conditions.

ELECTRODE: In automobiles the electrode usually refers to the insulated center rod of a spark plug. It is also sometimes used to refer to the rods attached to the shell of the spark plug.

ELECTROLYTE: A mixture of sulphuric acid and distilled water used in storage batteries of the wet type. See Storage Battery Section.

ELECTRO-MAGNET: A coil of insulated wire wound around an iron rod or series of rods will magnetize the rod or rods and cause it to attract any other iron in the vicinity provided an electrical current is passed through the wire. An example of this is a solenoid magnet. See Electrical Section.

ELEMENT: One set of positive plates and one set of negative plates complete with separators assembled together.

ELLIOTT STEERING KNUCKLE: Type of axle wherein the ends of the axle beam straddle the spindle.

E.M.F. (Electromotive Force or Voltage): See Electrical Section.

EMULSION: A milk-like viscous mixture of two liquids.

EMULSION BLOCK: English term for jet cluster.

ENAMEL: A combination of varnish and coloring pigment. It is sometimes heated during or after application to provide a hard surface.

EN-BLOC: Refers to the cylinder block of an engine cast in one section.

ENERGY: The capacity for doing work.

ENGINE: As used in automobiles, the term applies to the prime source of power generation used to propel the vehicle.

ENGINE DISPLACEMENT: The sum of the displacement of all the engine cylinders. See Piston Displacement.

ETHYL GASOLINE: Gasoline to which Ethyl fluid has been added. Ethyl fluid is a compound of tetraethyl lead, ethylene dibromide and ethylene dichloride. The purpose of the material is to slow down and control the rate of burning of the fuel in the cylinder to produce an expansive force rather than an explosive force and thus reduce detonation or "knocking" in an engine.

EVAPORATION: The progress of changing from a liquid to a vapor, such as boiling water to produce steam; evaporation is the opposite of condensation.

EXCITER: Often used in referring to the third brush where this mode of regulation is used for a generator.

EXHAUST GAS ANALYZER: An instrument for determining the efficiency with which an engine is burning fuel.

EXHAUST PIPE: The pipe connecting the engine to the muffler to conduct the exhausted or spent gases away from the engine.

EXPANSION: An increase in size. For example, when a metal rod is heated it increases in length and perhaps also in diameter; expansion is the opposite of contraction.

EXTREME PRESSURE LUBRICANTS (E.P.): Is used to designate a lubricant to which has been added an ingredient to increase the lubricant's ability to withstand high pressures as between gear teeth.

FAHRENHEIT (F.): A scale of temperature measurement ordinarily used in English speaking countries. The boiling point of water is 212 degrees, Fahrenheit, as compared to 100 degrees Centigrade.

FEELER GAUGE: A metal strip or blade finished accurately with regard to thickness used for measuring the clearance between two parts; such gauges ordinarily come in a set of different blades graduated in thickness by increments of .001 in.

FELLOWS: English term for adjoining parts.

FERROUS METAL: Metals which contain iron or steel and are therefore subject to rust.

F-HEAD ENGINE: An engine designed with one valve in the cylinder block at the side of the piston and the other valve in the cylinder head above the piston.

FIELD: In a generator or electric motor the area in which magnetic flow occurs. See Electrical Section.

FIELD COIL: A coil of insulated wire surrounding the field pole.

FILE: To finish or trim with a hardened rasp or file.

FILLET: A rounded filling between two parts joined at an angle.

FILTER (Oil, Water, Gasoline, Etc.): A unit containing an element, such as a screen of varying degrees of fineness. The screen or filtering element is made of various materials depending upon the size of the foreign particles to be eliminated from the fluid being filtered.

FIREWALL: Refers to the insulated partition between the engine and the vehicle occupants.

FIT: A kind of contact between two machined surfaces.

FLANGE: A projecting rim or collar on an object for keeping it in place.

FLASH POINT: The temperature at which an oil when heated will flash and burn.

FLOAT: A hollow tank which is lighter than the fluid in which it rests and which is ordinarily used to operate automatically a valve controlling the entrance of the fluid.

FLOATING PISTON PIN: A piston pin which is not locked in the connecting rod or the piston, but is free to turn or oscillate in both the connecting rod and the piston.

FLOATING POWER: A system of mounting or supporting an engine whereby the center of gravity of the engine is disposed on a line extending from one mounting to the other. This allows the engine to oscillate or float around its axis.

FLOAT LEVEL: The pre-determined height of the fuel in the carburetor bowl, usually regulated by means of a suitable valve.

FLUID DRIVE: A pair of vaned rotating elements held in position close to each other without touching. Rotation is imparted to the driven member by the driving member through the resistance of a body of oil. See Transmission Section.

"FLUTTER" OR "BOUNCE": As applied to engine valves, refers to a condition wherein the valve is not held tightly on its seat during the time the cam is not lifting it.

FLUX, ELECTRIC OR MAGNETIC: Lines of magnetic force passing or flowing in a magnetic field.

FLUX, SOLDERING, WELDING, BRAZING: The material used to cause the joining metal to adhere to both parts to be joined.

FLYWHEEL: A heavy wheel in which energy is absorbed and stored by means of momentum.

FOOT POUND (or lbs. ft.): This is a measure of the amount of energy or work required to lift 1 lb. 1 ft.

FORCE-FIT: Also known as a press-fit or drive-fit. This term is used when the shaft is slightly larger than the hole and must be forced in place.

FORGE: To shape metal while hot and plastic by hammering.

FOUR CYCLE ENGINE: Also known as Otto cycle, wherein an explosion occurs every other revolution of the crankshaft; a cycle being considered as 1/2 revolution of the crankshaft. These strokes are (1) suction stroke; (2) compression stroke; (3) power stroke; (4) exhaust stroke.

FREE-WHEELING: A mechanical device which will engage the driving member to impart motion to a driven member in one direction but not the other. Also known as an overrunning clutch. See Transmission Overdrives.

FREON: A material used in the circulation system of a refrigerator.

FRICTION DRIVE: A method of power transmission used on early automobiles whereby power is transmitted from a driving to a driven wheel by means of pressing one wheel against another at a right angle.

FUEL KNOCK: Same as detonation.

FULCRUM: The support on which a lever turns in moving a body.

FULL-FLOATING AXLE: A drive axle construction wherein the axle driving shaft does not carry any of the car weight.

FUSE: A fuse consists of a piece of wire which will carry a limited amount of current only. It is placed in an electrical circuit as a safety measure to avoid damage and is designed to melt and open the circuit in case of excessive current flow.

GAL.: Gallon.

GALVANIZE: To coat with a molten alloy of lead and tin to prevent rusting.

GALVANOMETER: An instrument used for the location, measurement and direction of an electric current.

GAS: A substance which can be changed in volume and shape according to the temperature and pressure applied to it. For example, air is a gas which can be compressed into smaller volume and into any shape desired by pressure. It can also be expanded by the application of heat.

GASSING: The bubbling of the battery electrolyte which occurs during the process of charging a battery.

GASKET: Anything used as a packing, such as a non-metallic substance placed between two metal surfaces to act as a seal.

GEAR RATIO: The number of revolutions made by a driving gear as compared to the number of revolutions made by a driven gear of different size. For example, if one gear makes three revolutions while the other gear makes one revolution, the gear ratio would be 3 to 1.

GENERATOR: A device consisting of an armature, field coils and other parts which when rotated will generate electricity. In automobiles it is usually driven by a belt from the engine crankshaft. See Electrical Section for details.

GLAZE: As used to describe the surface of the cylinder, an extremely smooth or glossy surface such as a cylinder wall highly polished over a long period of time by the friction of the piston rings.

GLAZE BREAKER: A tool for removing the glossy surface finish in an engine cylinder.

GOVERNOR: A device to control and regulate speed. May be mechanical, hydraulic or electrical.

GRAM: A metric unit of weight which is equal to 1/454th part of a pound.

GRID: The metal framework of an individual battery plate in which the active material is placed.

GRIND: To finish or polish a surface by means of an abrasive wheel.

GROUND: In automotive use one terminal of the battery is insulated and the other is attached to the metal frame of the vehicle or "ground"; thus by connecting one terminal of each electrically operated unit to the frame of the vehicle only one insulated wire is required to carry the current to the unit, as the frame serves as a return wire.

GROUP: In a battery a set of plates either positive or negative joined together but not assembled with separators.

GROWLER: An electrical device for testing electric motor or generator armatures.

GUDGEON PIN: Also known as "wrist pin" and piston pin. This is the pin that connects the connecting rod to the piston and piston pin is the preferred term.

GUM: In automotive fuels, this refers to oxidized petroleum products which accumulate in the fuel system, carburetor or engine parts.

HARD ON: English term for tight.

HARD PEDAL: A loss in braking efficiency so that an excessive amount of pressure is needed to actuate the brakes.

HARD SOLDER: Uniting two pieces of metal with a material having a melting point higher than "soft" solder. An example is silver soldering wherein silver is used instead of lead-tin alloy.

HARMONIC BALANCER: A device to reduce the torsional or twisting vibration which occurs along the length of the crankshaft used in multiple cylinder engines. Also known as a vibration damper.

H.C.: High compression.

HEAT EXCHANGER: Sometimes used to describe a vaporizer.

HEAT RISER: The passage in the manifold between the exhaust and intake manifold.

HEAT TREATMENT: A combination of heating and cooling operations timed and applied to a metal in a solid state in a way that will produce desired properties.

HEEL: The outside or larger half of the gear tooth; also see Brake Shoe Heel.

HELICAL: Shaped like a coil of wire or a screw thread.

HELICAL GEAR: A gear design wherein the gear teeth are cut at an angle to the shaft.

HERRINGBONE GEAR: A pair of helical gears designed to operate together in which the angle of the pair of gears forms a V.

HIGH TENSION: As used in automotive electricity, it refers to the secondary or induced high voltage electrical current; includes the wiring from the cap of the ignition distributor to the coil and to each of the spark plugs.

HONE: An abrasive tool for correcting small irregularities or differences in diameter in a cylinder, such as an engine cylinder or a brake cylinder.

HOTCHKISS DRIVE: A driving axle design wherein the axle torque is absorbed by the chassis springs.

HOT SPOT: Refers to a comparatively thin section or area of the wall between the inlet and exhaust manifold of an engine, the purpose being to allow the hot exhaust gases to heat the comparatively cool incoming mixture. Also used to designate local areas of the cooling system which have attained above average temperatures.

HP: Horsepower, the energy required to lift 550 lbs. 1 ft. in 1 second.

HUNTING LINK: A section of thin leaves used in a timing chain with an odd number of links. Can be removed to shorten the chain.

HYDRAULIC: Pertains to fluids in motion, such as hydraulically operated brakes, hydraulic torque converters, power steering, etc.

HYDROCARBON: Any compound composed entirely of carbon and hydrogen, such as petroleum products.

HYDROCARBON ENGINE: An engine using petroleum products, such as gas, liquefied gas, gasoline, kerosene or fuel oil as a fuel.

HYDROMETER: An instrument for determining the state of charge in a battery by finding specific gravity of the electrolyte.

HYDROSTATIC GAUGE: Used in referring to gauges, such as a gasoline tank gauge wherein the depth of the gasoline tank controls the air in the connecting line to the instrument which registers the depth on a scale or dial.

HYPOID GEARS: A design of pinion and ring gear wherein the center line of the pinion is offset from the center line of the ring gear. Often used in automobile rear axle to permit the driveshaft to be lowered to reduce gear contact noise by the sliding action of the spiral teeth and to allow more gear tooth surface to be in contact thus providing greater strength.

ICEI: Internal Combustion Engine Institute, Inc.

I.D.: Inside Diameter.

IDLE: Refers to the engine operating at its slowest speed with a vehicle not in motion.

IGNITION DISTRIBUTOR: An electrical unit usually containing the circuit breaker for the primary circuit and providing a means for conveying the secondary or high tension current to the spark plug wires as required.

IGNITION SYSTEM: The means for igniting the fuel in the cylinders; includes spark plugs, wiring, ignition distributor, ignition coil and source of electrical current supply.

I.H.P.: Indicated horsepower developed by an engine and a measurement of the pressure of the explosion within the cylinder expressed in pounds per square inch.

IN.: Inch.

INCLUDED ANGLE: As used in automobile steering systems, the combined angles of the camber and kingpin inclination.

INDEPENDENT SUSPENSION: A construction whereby the wheel on one side of the vehicle may rise or fall independently of the wheel on the other side.

INDUCTION: The influence of magnetic fields of different strength not electrically connected to one another.

INDUCTION COIL: Essentially a transformer which through the action of induction creates a high tension current by means of an increase in voltage.

INERTIA: A physical law which tends to keep a motionless body at rest or also tends to keep a moving body in motion; effort is thus required to start a mass moving or to retard or stop it once it is in motion.

INHIBITOR: A material to restrain or hinder some unwanted action, such as a rust inhibitor which is a chemical added to cooling systems to retard the formation of rust.

INJECTOR: As used on automobiles, a pump which injects or inserts a fluid or gas usually against pressure into a cylinder or chamber.

INLET VALVE OR INTAKE VALVE: A valve which permits a fluid or gas to enter a chamber and seals against exit.

INPUT SHAFT: The shaft carrying the driving gear, such as in a transmission by which the power is applied.

INSULATION: Any material which does not conduct electricity; used to prevent the flow or leakage of current from a conductor. Also used to describe a material which does not conduct heat readily.

INSULATOR: An electrical conductor covered or shielded with a non-conducting material, such as a copper wire within a rubber tube.

INTAKE MANIFOLD OR INLET PIPE: The tube used to conduct the gasoline and air mixture from the carburetor to the engine cylinders.

INTEGRAL: The whole made up of parts.

INTENSIFY: To increase or concentrate, such as to increase the voltage of an electrical current.

INTERMEDIATE GEAR: In an automobile transmission the gear or gears between low and high; in a three-speed transmission, the second speed.

INTERMITTENT: Motion or action that is not constant but occurs at intervals.

INTERNAL COMBUSTION: The burning of a fuel within an enclosed space.

INTERRUPTER: A device for interrupting an electrical circuit; often automatic and may be known as "contact breaker," "circuit breaker," "cut-out" or "relay."

JAR: In a battery the rubber or composition container for a battery cell.

JOURNAL: A bearing within which a shaft operates.

JUMP SPARK: A high tension electrical current which jumps through the air from one terminal to the other.

JUNK RING: A flexible ring used in the cylinder head to provide a seal with the inner sleeve of a sleeve valve engine.

KEY: A small block inserted between the shaft and hub to prevent circumferential movement.

KEYWAY OR KEYSEAT: A groove or slot cut to permit the insertion of a key.

KICK-DOWN SWITCH: An electrical switch used to cause a transmission to down-shift from a higher to a lower gear ratio.

KILOMETER: A metric measurement of distance which is the equivalent of 5/8 of a mile.

KILOWATT: A measure of electrical energy consisting of 1,000 watts; it is equal to 1 1/3 horsepower.

KINGPIN: The shaft or journal upon which and around which the steering spindle of an automobile front wheel revolves.

KINGPIN INCLINATION: The angle at which the kingpin is inclined sidewise from the vertical on the front wheel of an automobile.

KNURL: To indent or roughen a finished surface.

KNOCK: A general term used to describe various noises occurring in an engine; may be used to describe noises made by loose or worn mechanical parts, pre-ignition, detonation, etc.

LACQUER: Lacquer as used for painting an automobile is a solution of solids in solvents which evaporate with great rapidity.

LAMINATE: To build up or construct out of a number of thin sheets. An example is the laminated core in an electric motor or generator.

LAPPING: The process of fitting one surface to another by rubbing them together with an abrasive material between the two surfaces.

LB.: Pound.

L.C.: Low compression.

LEAD BURNING: Joining two pieces of lead by melting or fusing the metal.

L-HEAD ENGINE: An engine design in which both valves are located on one side of the engine cylinder.

LIMOUSINE: A type of automobile body wherein the operator is separated from the passengers by a partition.

LINER: Usually a thin section placed between two parts, such as a replaceable cylinder liner in an engine.

LINKAGE: Any series of rods, yokes, and levers, etc., used to transmit motion from one unit to another.

LIQUID: Any substance which assumes the shape of the vessel in which it is placed without changing volume.

LIQUID WITHDRAWAL SYSTEM: A method of piping and connecting whereby liquid is taken from the bottom of an L.P.G. tank and converted into gas by a vaporizer.

LITER: A metric measure equal to 2.11 pints.

LITHARGE: Lead monoxide, a yellow earthy substance which when mixed with glycerin forms a hard-setting cement for metal seals.

LIVE: Electrical parts connected to the insulated side of the electrical system, such as an insulated wire connected to the battery and often referred to as the "hot" wire.

LIVE AXLE: The shaft through which the power travels from the drive axle gears to the driving wheels.

LOST MOTION: Motion between a driving part and a driven part which does not cause actuation of the driven part. Also see Backlash.

LOUVER OR LOUVRE: Openings or vents in the hood or body of a vehicle usually intended for ventilation.

LOW PEDAL: A condition wherein excessive clearance exists at some point in the braking system so that excess pedal movement is required for application of the brakes.

LOW SPEED: The gearing provided in an automobile which causes the greatest number of revolutions of the engine as compared to the driving wheels.

L.P.G., LIQUEFIED PETROLEUM GAS: Made usable as a fuel for internal combustion engines by compressing volatile petroleum gases to liquid form. When so used, must be kept under pressure or at low temperature in order to remain in liquid form.

LUG: The extension of the plate grid of a battery for connecting the plate to the strap.

LUGGAGE BOOT: English name for trunk.

MAGNET (Permanent): A piece of hard steel often bent into a "U" shape so as to have opposite poles and which can be charged with and retain magnetic power.

MAGNETIC FIELD: The flow of magnetic force or magnetism between the opposite poles of a magnet.

MAGNETO: An electrical device which generates alternating current when rotated by an outside source of power; may be used for the generation of either low tension or high tension current.

MAKE-AND-BREAK IGNITION: A low tension ignition system used in early automobiles not equipped with spark plugs. In this case the spark occurred within the cylinder by mechanical closing and opening of the circuit rather than by being required to jump the air gap in a spark plug.

MALLEABLE CASTING: A casting which has been toughened by annealing.

MANIFOLD: A pipe with multiple openings used to connect various cylinders to one inlet or outlet.

MANGANESE BRONZE: An alloy of copper, zinc and manganese.

MANOMETER: A device for measuring a vacuum consisting of a "U" shaped tube partially filled with fluid. One end of the tube is open to the air and the other is connected to the chamber in which the vacuum is to be measured. A column of Mercury 30 in. high equals 14.7 lbs. per square in. which is atmospheric pressure at sea level. Readings are given in terms of inches of Mercury.

MASTER CYLINDER: The single hydraulic cylinder which is used to force the hydraulic fluid to the individual wheel cylinders in applying the brakes.

MECHANICAL EFFICIENCY (Engine): The ratio between the indicated horsepower and the brake horsepower of an engine.

MEMA: Motor and Equipment Manufacturers Association.

MERCURY COLUMN: A reference term used in connection with a Manometer.

METHANOL OR WOOD ALCOHOL. A poisonous alcohol made from distillation of wood; can also be made synthetically.

MEWA: Motor and Equipment Wholesalers Association.

MICROMETER: A measuring instrument for either external or internal measurement in thousandths and sometimes tenths of thousandths of inches.

MILL: To cut or machine with rotating tooth cutters.

MILLIMETER (mm.): One millimeter is the metric equivalent of .039370 of an inch or one inch being the equivalent of 25.4 mm.

MISFIRING: Failure of an explosion to occur in one or more cylinders while the engine is running; may be continuous or intermittent failure.

MODULATOR: A pressure regulating or governor device used in automatic transmissions.

MONO-BLOCK: Meaning that all cylinders of an engine are contained in one casting; the same as en-bloc or in-block.

MOTOR: Actually this term should be used in connection with an electric motor and should not be used when referring to the engine of an automobile.

M.P.H.: Miles per hour.

MUFFLER: A chamber attached to the end of the exhaust pipe which allows the exhaust gases to expand and cool. It is usually fitted with baffles or porous plates and serves to subdue much of the noise created by the exhaust.

MULTIPLE DISK: Refers to a clutch having a number of driving and driven disks as compared to a single plate clutch.

NADA: National Automobile Dealers Association.

NAPA: National Automotive Parts Association.

NBFU: National Board of Fire Underwriters.

NEEDLE BEARING: An anti-friction bearing using a great number of small diameter rollers of greater length; also known as a quill type bearing.

NEGATIVE POLE: The point to which an electrical current returns after passing through the circuit. It is designated by a minus sign (-).

NEON GAS: A rare element of the air which has low electrical resistance and is therefore a good conductor for electricity. When placed in a closed glass tube and connected to a high tension electric current, the gas gives off a bright glow.

NFPA: National Fire Protection Association.

NICKEL STEEL: Nickel is alloyed with steel to form a heat and corrosion resistant metal.

NIPPLE: English term for lubrication fitting.

NON-FERROUS METALS: This designation includes practically all metals which contain no iron or very little iron and are therefore not subject to rusting.

NORTH POLE: The pole of a magnet from whence the lines of force start; the opposite of south pole.

NSPA: National Standard Parts Association.

OCTANE NUMBER: A unit of measurement on a scale intended to indicate the tendency of a fuel to detonate or knock.

OCTANE SELECTOR: A calibrated device for adjusting the timing of the ignition distributor in accordance with the characteristics of the fuel in use.

O.D.: Outside diameter.

ODOMETER: A device for measuring and registering the number of miles traveled.

OHM: A measurement of the resistance to the flow of an electrical current through a conductor.

OIL PUMPING: A term used to describe an engine which is using an excessive amount of lubricating oil.

OPEN CIRCUIT: A break or opening in an electrical circuit which interferes with the passage of the current.

OSCILLATE: To swing back and forth like a pendulum.

OSCILLOSCOPE: An electrical testing device which provides an image on a screen of the spark ignition action.

OTTO CYCLE: Also called four stroke cycle. Named after the man who adopted the principle of four cycles of operation for each explosion in an engine cylinder. They are (1) suction stroke, (2) compression stroke, (3) power stroke, (4) exhaust stroke.

OUTPUT SHAFT: The shaft or gear which delivers the power from a device, such as a transmission.

OVERDRIVE: Any arrangement of gearing which produces more revolutions of the driven shaft than of the driving shaft.

OVERHEAD VALVE OR VALVE-IN-HEAD ENGINE: An engine design having valves located in the cylinder head directly above the pistons.

OVERRUN COUPLING: A free-wheeling device to permit rotation in one direction but not in the other.

OXIDIZE: To combine an element with oxygen or convert into its oxide. The process is often accomplished by combination; for example, when carbon burns, it combines with oxygen to form carbon dioxide or carbon monoxide. An example is rusted iron wherein the iron has combined with the oxygen in the air to form an oxide of iron or in other words rust.

"PANCAKE" ENGINE: A design wherein the cylinders are laid on their side or horizontal in order to obtain a minimum of height; for example, where it is desired to place the engine under the floor boards of a bus.

PARAFFIN: English name for kerosene.

PARKING BRAKE: May be either a separate system or a separate application of the service brake so that the brake may be held in the applied position indefinitely.

PAWL: A pivoted bar adapted to engage with the teeth of a ratchet or the like used either to prevent or impart motion.

PEEN: To stretch or clinch over by pounding with the rounded end of a hammer.

PERIPHERY: The circumference of a circle such as the tread of a tire.

PETCOCK: A small valve placed at various points in a fluid circuit usually for draining purposes.

PETROL: European name for gasoline.

PETROLEUM: A group of liquid and gaseous compounds composed of carbon and hydrogen which are removed from the earth.

PHILLIPS SCREW OR SCREWDRIVER: A type of screw head having a cross instead of a slot for a corresponding type of screwdriver.

PHOSPHOR-BRONZE: An alloy consisting of copper, tin and lead sometimes used in heavy duty bearings.

PILOT VALVE: A small valve used to control the action of a larger, such as a main valve.

PINION: A small gear having the teeth formed in the hub.

PINION CARRIER: The mounting or bracket which retains the bearings supporting a pinion shaft.

PINKING: English term for pinging.

PISTON: A cylindrical part closed at one end which is connected to the crankshaft by the connecting rod. The force of the explosion in the cylinder is exerted against the closed end of the piston causing the connecting rod to move the crankshaft.

PISTON COLLAPSE: A condition describing a collapse or a reduction in diameter of the piston skirt due to heat or stress.

PISTON DISPLACEMENT: The volume of air moved or displaced by moving the piston from one end of its stroke to the other.

PISTON HEAD: That part of the piston above the rings.

PISTON LANDS: Those parts of a piston between the piston rings.

PISTON PIN: The journal for the bearing in the small end of an engine connecting rod which also passes through piston walls; also known as a wrist pin.

PISTON RING: An expanding ring placed in the grooves of the piston to provide a seal to prevent the passage of fluid or gas past the piston.

PISTON RING EXPANDER: A spring placed behind the piston ring in the groove to increase the pressure of the ring against the cylinder wall.

PISTON RING GAP: The clearance between the ends of the piston ring.

PISTON RING GROOVE: The channel or slots in the piston in which the piston rings are placed.

PISTON SKIRT: That part of the piston below the rings.

PISTON SKIRT EXPANDER: A spring or other device inserted in the piston skirt to compensate for collapse or decrease in diameter.

PITMAN ARM: The lever extending from the steering gears to which the drag link is attached.

PITOT TUBE: An instrument for measuring fluid velocity by means of the difference in pressure between the tip and side openings.

PIVOT: A pin or short shaft upon which another part rests or turns or upon and about which another part rotates or oscillates.

PLANETARY GEARS: A system of gearing which is modeled after the solar system. A pinion is surrounded by an internal ring gear and planet gears are in mesh between the ring gear and pinion around which all revolves.

PLANET CARRIER: In a planetary gear system the carrier or bracket in a planetary system which contains the shafts upon which the pinions or planet gears turn.

PLANET GEARS: The pinions of gears interposed between the ring gear and sun gear and meshing with both in a planetary system.

PLATINUM: An expensive metal having an extremely high melting point and good electrical conductivity. Often used in magneto breaker points.

POLARITY: Refers to the positive or negative terminal of a battery or an electric circuit; also the north or south pole of a magnet.

POPPET VALVE: A valve structure consisting of a circular head with an elongated stem attached in the center which is designed to open and close a circular hole or port.

PORCELAIN: General term applied to the material or element used for insulating the center electrode of a spark plug.

PORT: In engines, the openings in the cylinder block for valves, exhaust and inlet pipes, or water connections. In two-cycle engines the openings for inlet and exhaust purposes.

"PORTING": As applied to racing engines, the enlarging, matching, streamlining and polishing of the inside of the manifolds and valve ports to reduce the friction of the flow of gases.

POSITIVE POLE: The point from whence the current flows to the circuit. This is designated by a plus sign (+).

POST: The heavy circular part to which the group of plates is attached and which extends through the cell cover to provide a means of attachment to the adjacent cell or battery cable.

POTENTIAL: An indication of the amount of energy available.

POTENTIAL DIFFERENCE: A difference of electrical pressure which sets up a flow of electric current.

POTENTIAL DROP: A loss of electrical pressure due to resistance or leakage.

POWER STEERING: The application of hydraulic or mechanical power in addition to manual power in the steering of an automobile.

PREFOCUSSED LAMP BULB: A bulb construction in which the focus is not adjustable.

PRE-HEATING: The application of heat as a preliminary step to some further thermal or mechanical treatment.

PRE-IGNITION: Ignition occurring earlier than intended. For example, the explosive mixture being fired in a cylinder as by a flake of incandescent carbon before the electric spark occurs.

PRE-LOADING: To place a small amount of pressure or tension on an anti-friction bearing by adjustment to eliminate any semblance of looseness.

PRESS-FIT: Also known as a force-fit or drive-fit. This term is used when the shaft is slightly larger than the hole and must be forced in place.

PRIMARY BRAKE SHOE: The brake shoe in a set which generates the self energizing action.

PRIMARY WINDING: In an ignition coil or magneto armature is a wire which conducts the low tension current which is to be transformed by induction into high tension current in the secondary winding.

PRIMARY WIRES: The wiring circuit used for conducting the low tension or primary current to the points where it is to be used.

PROGRESSIVE TRANSMISSION: An early type of transmission in which it was necessary to go through all of the intermediate gears when shifting from the lowest to the highest gears and vice versa; was abandoned in favor of the selective type.

PRONY BRAKE: A machine for testing the power of an engine while running against a friction brake.

PROPANE: A petroleum hydrocarbon compound which has a boiling point about -44 degrees, F. and which is used as an engine fuel; loosely referred to as L.P.G. and often combined with Butane.

PROPELLER SHAFT: The shaft connecting the transmission with the rear axle.

P.S.I.: A measurement of pressure in pounds per square inch.

PUSH ROD: A connecting link in an operating mechanism, such as the rod interposed between the valve lifter and rocker arm on an overhead valve engine.

QUADRANT: A term originally applied to the section of a circle on the steering post to which the spark and throttle controls were connected. Later used to designate the gearshift or transmission control lever selective mounting.

QUENCHING: A process of rapid cooling of hot metal by contact with liquid, gases or solids.

QUILL BEARING: See Needle Bearing.

RACE: As used with reference to bearings, a finished inner and outer surface in which or on which balls or rollers operate.

"RACE-CAM": A type of camshaft for race cars which increases the lift of the valve, increases the speed of valve opening and closing, increases the length of time the valve is held open, etc. Also known as "Full," "Three-quarter" or "Semi-race cams," depending upon design.

RADIAL ENGINE: An engine construction wherein the cylinders are mounted in a row of circle around the crankcase.

RADIATION: The transfer of heat by rays, such as heat from the sun.

RADIUS RODS: As used on automobiles, means rods attached to the axle and to the frame to maintain correct horizontal position of the axle and yet permit vertical motion.

RATIO: The relation or proportion that one number bears to another.

REACTOR: As used in torque converters, means a wheel having curved blades interposed between the pump and turbine wheels of a torque converter.

REAM: To finish a hole accurately with a rotating fluted tool.

RECIPROCATING: A back and forth movement, such as the action of a piston in a cylinder.

RECTIFIER: An electrical device for transforming or changing alternating current into direct current.

REFRIGERANT: A material used in the circulation system of a refrigerator which absorbs and conveys heat.

REGULATOR: An automatic pressure reducing or regulating valve.

RELAY: A device for interrupting an electrical circuit; often automatic and may be known as "circuit breaker," "interrupter," "contact breaker," or "cut-out."

RELIEF: The amount one surface is set below or above another surface.

"RELIEVING": As applied to racing engines, the removal of some metal from around the valves and between the cylinder and valves to facilitate flow of the gases.

RESISTOR: A current consuming piece of metal wire or carbon inserted into an electrical circuit to decrease the flow.

RETARD: When used with reference to an ignition distributor, means to cause the spark to occur at a later time in the cycle of engine operation; opposite of spark advance.

REVERSE ELLIOT STEERING KNUCKLE: Type of axle construction wherein the steering spindle straddles the ends of the axle beam.

RIGHT HOME: English term for all the way in.

RING GEAR: May be applied to the outer gear within which the other gears revolve in a planetary system or may refer to the driven gear which mates with the drive pinion in a differential assembly.

RIVET: To attach with rivets or to batter or upset the end of a pin.

RMA: The Rubber Manufacturers Association.

ROCKER ARM: In an automobile engine a lever located on a fulcrum or shaft, one end of the lever being on the valve stem; the other being on the push rod.

ROCKWELL HARNESS: A scale for designating the degree of hardness possessed by a substance.

ROLLER BEARING: An inner and outer race upon which hardened steel rollers operate.

ROTARY ENGINE: An engine construction wherein the crankshaft remains stationary and the cylinders spin around it as in a pin wheel.

ROTARY VALVE: A valve construction in which ported holes come into and out of register with each other to allow entrance and exit of fluids or gases.

ROTOR: Rotating valve or conductor for carrying fluid or electrical current from a central source to the individual outlets as required.

R.P.M.: Revolutions per minute.

RUBBER: An elastic vibration absorbing material of either natural or synthetic origin.

RUNNING-FIT: Where sufficient clearance has been allowed between the shaft and journal to allow free running without overheating.

SAE: Society of Automotive Engineers.

SAE STEELS: A numerical index system used to identify composition of SAE steel. Basically the first digit indicating the type to which the steel belongs; thus (1) indicates a carbon steel, (2) a nickel steel, etc. The second digit generally indicates the approximate percentage of the predominant alloying element. Usually the last two or three digits indicates the approximate average carbon content in points or hundredths of 1 per cent. Thus (SAE 2340 steel) indicates a nickel steel of approximately 3 per cent nickel and 40 per cent carbon.

SAE THREAD: Refers to a table of threads set up by the Society of Automotive Engineers and determines the number of threads per inch. For example, a quarter inch diameter rod with an SAE thread would have 28 threads per inch.

SAFETY FACTOR: The degree of surplus strength over and above normal requirements which serves as insurance against failure.

SAFETY RELIEF VALVE: A spring loaded valve designed to open and thus relieve excessive pressure in a vessel when it exceeds a predetermined safe point.

SAND BLAST: To clean a surface by means of sand propelled by compressed air.

SAYBOLT TEST: A method of measuring the viscosity of oil with the use of a viscosimeter.

SCALE: A flaky deposit occurring on steel or iron. Ordinarily used to describe the accumulation of minerals and metals accumulating in an automobile cooling system.

SCORE: A scratch, ridge or groove marring a finished surface.

SCOTCHES: English term for blocks.

SCUTTLE: Air intake vent in England.

SEALED BEAM LAMPS: In this construction the reflector, lens and filament are hermetically sealed in one unit.

SEALING COMPOUND: A readily melted acid-proof non-conducting material used in sealing the battery cover in the jar. Similar to asphalt.

SEAT: A surface, usually machined, upon which another part rests or seats; for example, the surface upon which a valve face rests.

SECONDARY BRAKE SHOE: The brake shoe in a set which is energized by the primary shoe and increases the servo, or self-energization, action of the brake.

SECONDARY WINDING: In an ignition coil or magneto armature, a wire in which a secondary or high tension current is created by induction due to the interruption of the current in the adjacent primary winding.

SEDIMENT: In a battery this refers to the active material of the plates which is gradually shed and accumulates in a space provided below the plates.

SEIZE: When one surface moving upon another scratches, it is said to seize. An example is a piston score or abrasion in a cylinder due to lack of lubrication or over-expansion.

SELECTIVE TRANSMISSION: An arrangement of gearing and shifting device wherein it is possible to go directly from neutral position into any desired pair of gears.

SELF-ENERGIZATION: As applied to brakes, the placing of the shoes in such position that the drum tends to drag the lining along with it. The result is a wedging action between the anchor and the drum.

SEMI-DIESEL: A semi-Diesel engine operates on comparatively high compression and utilizes solid injection of the fuel. However, it does use an electrical ignition system rather than depend solely upon the heat generated by compression to furnish ignition.

SEMI-FLOATING AXLE: A drive axle construction wherein the axle driving shafts support the weight of the car.

SEPARATORS: Sheets of rubber or wood inserted between the positive and negative plates of a cell to keep them out of contact with each other.

SERIES WINDING: An electric winding or coil of wire in series with other electrical equipment. When applied to electric generators or motors, the field coil is connected in series with the armature. See Electrical Section.

SERVO: In automatic transmissions, is a hydraulic piston and cylinder assembly used to control drum bands.

SERVO ACTION: A brake construction wherein a primary shoe pushes a secondary shoe to generate self-energization.

SHACKLE BOLT: A link for connecting one end of a chassis spring to the frame which allows the spring end to oscillate laterally.

SHEAR: To cut between two blades.

SHIM: Thin sheets used as spacers between two parts, such as the two halves of a journal bearing.

"SHIMMY": Applied to automobile steering, a wobbling or shaking of the front wheels.

SHOCK ABSORBER: A device to provide mechanical or hydraulic friction to the action of automobile springs to control excessive deflection.

SHORT CIRCUIT: To provide a shorter path; often used to indicate an accidental ground in an electrical device or conductor.

SHRINK-FIT: Where the shaft or part is slightly larger than the hole in which it is to be inserted. The outer part is heated above its normal operating temperature or the inner part chilled below its normal operating temperature or both and assembled in this condition; upon cooling an exceptionally tight fit is obtained.

SHUNT: To by-pass around or turn aside; in electrical apparatus an alternate path for the current.

SHUNT WINDING: An electric winding or coil of wire, which forms a by-pass or alternate path for electric current. When applied to electric generators or motors, each end of the field winding is connected to an armature brush. See Electrical Section.

SHUTTLE VALVE: A valve for diverting pressure from one channel to another.

SILENCER: Same as Muffler.

SILICONE STEEL: An alloy of silicone and chromium with steel. As this alloy resists burning and oxidation and does not warp readily, it is often used for exhaust valves of internal combustion engines.

SILVER SOLDERING: Same as Hard Soldering.

SLEEVE VALVE: A reciprocating sleeve or sleeves with ported openings placed between the piston and cylinders of an engine to serve as valves.

SLIDING-FIT: Where sufficient clearance has been allowed between the shaft and journal to allow free running without overheating.

SLIP-IN BEARING: A liner made to extremely accurate measurements which can be used for replacement purposes without additional fitting.

SLUDGE: As used in connection with automobile engines, indicates a composition of oxidized petroleum products along with an emulsion formed by the mixture of oil and water. This forms a pasty substance and clogs oil lines and passages and interferes with engine lubrication.

SOLDER: An alloy of lead and tin used to unite two metal parts.

SOLDERING: To unite two pieces of metal with a material, such as solder having a comparatively low melting point.

SOLENOID: An iron core surrounded by a coil of wire which moves due to magnetic attraction when an electrical current is fed to the coil; often used to actuate mechanisms by electrical means.

SOLID INJECTION: The system used in full Diesel and semi-Diesel, wherein fuel in the fluid state is injected into the cylinder rather than a mixture of air and fuel drawn from a carburetor.

SOLVENT: A solution which dissolves some other material. For example, water is a solvent for sugar.

SOUTH POLE: The pole of a magnet to which the lines of force flow; the opposite of north pole.

SPANNER: English name for wrench.

SPARK: An electrical current possessing sufficient pressure to jump through the air from one conductor to another.

SPARK ADVANCE: When used with reference to an ignition distributor, means to cause the spark to occur at an earlier time in the cycle of engine operation; opposite of retard.

SPARK GAP: The space between the electrodes of a spark plug through which the spark jumps. Also a safety device in a magneto to provide an alternate path for the current when it exceeds a safe value.

SPARK KNOCK: Same as Pre-ignition.

SPARK PLUG: A device inserted into the combustion chamber of an engine containing an insulated central electrode for conducting the high tension current from the ignition distributor or magneto. This insulated electrode is spaced a pre-determined distance from the shell or side electrode in order to control the dimensions of the gap for the spark to jump across.

SPECIFIC GRAVITY: The relative weight of a substance as compared to water. For example, if a cubic inch of acid weighs twice as much as a cubic inch of water, the specific gravity of the substance would be 2.

SPEEDOMETER: A device for measuring and indicating the speed of a vehicle in miles per hour.

SPIN: As applied to metal work, to shape sheet metal by forcing it against a form as it revolves.

SPIRAL BEVEL GEAR: A ring gear and pinion wherein the mating teeth are curved and placed at an angle with the pinion shaft.

SPLAYED SPRING: A design in which the leaf springs are placed at other than a 90 degree angle to the axle.

SPLINE: A long keyway.

SPLINE JOINT: Two mating parts each with a series of splines around their circumference, one inner and one outer in order to provide a longitudinally movable joint without circumferential motion.

"SPONGY" BRAKE PEDAL: Air in the hydraulic lines, distortion or stretching of connecting parts or swelling of hydraulic hose may allow the pedal to be spongy or springy instead of solid.

SPOT WELD: To attach in spots by localized fusion of the metal parts with the aid of an electric current.

SPRUNG WEIGHT: A term used to describe all parts of an automobile that are supported by the car springs, such as the frame, engine, body, etc. Unsprung weight includes wheels, axles, etc. that are not supported by the springs.

SPUR GEAR: A gear in which the teeth are cut parallel to the shaft.

SPURT-HOLE: A hole drilled through a connecting rod and bearing which allows oil under pressure to be squirted out of the bearing for additional lubrication of the cylinder walls.

SQ. FT.: Square feet.

SQ. IN.: Square inch.

STAMPING: A piece of sheet metal cut and formed into the desired shape with the use of dies.

STANDARD THREAD: Refers to the U.S.S. table of the number of threads per inch. For example, a quarter inch diameter standard thread would have 20 threads per inch.

STATIC ELECTRICITY: Atmospheric electricity as distinguished from electricity as produced by a mechanical device. Usually has extremely high tension.

STEEL CASTING: Cast iron to which varying amounts of scrap steel have been added.

STEERING GEAR: Actually means the gears in the steering unit, but is also applied to the assembly of parts and units required to control the angularity of the wheels to the body of a vehicle.

STEERING GEOMETRY: The related angles assumed by the front wheels of a vehicle when turning.

STEERING KNUCKLE: Also known as steering spindle.

STEERING POST OR COLUMN: The shaft connecting the steering gear unit with the steering wheel.

STEERING SPINDLE: A journal or shaft upon which the steerable wheels of a vehicle are mounted; also sometimes known as steering knuckle.

STELLITE: An alloy of cobalt, chrome and tungsten which is often used for exhaust valve seat inserts. It has a high melting point, good corrosion resistance and unusual hardness when hot.

STRAP: In a battery, refers to a lead section to which the plates of a group are joined.

STRESS: The force or strain to which a material is subjected.

STROBOSCOPE: A term applied to an ignition timing light which by being attached to the distributor points gives the effect of making a marking on a rapidly rotating wheel, such as a flywheel, appear to stand still for observation.

STROKE: In an automobile engine, the distance moved by the piston.

"STROKING": As applied to racing engines, remachining the crankshaft throws off center to alter the stroke.

STUDS: A rod with threads cut on both ends, such as a cylinder stud which screws into the cylinder block on one end and has a nut placed on the other end to hold the cylinder head in place.

SUCTION: Suction exists in a vessel when the pressure is lower than the atmospheric pressure; also see Vacuum.

SULPHATED: When a battery is improperly charged or allowed to remain in a discharged condition for some length of time, the plates will have an abnormal amount of lead sulphate. The battery is then said to be "sulphated."

SUN GEAR: The central gear around which the other gears revolve in a planetary gear system.

SUPERCHARGER: A blower or pump which forces air into the cylinders at higher than atmospheric pressure. In an engine the increased pressure forces more air into the cylinder, thus enabling more gasoline to be burned and more power produced.

SWEAT: To join metal pieces by clamping together with solder between them and applying heat.

SYNCHRO-MESH: A device used in transmission gearing to facilitate the meshing of two gears by causing the speed of both gears to coincide at the same time.

SYNCHRONIZE: To cause two events to occur in unison or at the same time. For example, to time a mechanism so that two or more sparks will occur at the same instant.

TACHOMETER: A device for measuring and indicating the rotative speed of an engine.

TAP: To cut threads in a hole with a tapered, fluted, threaded tool. In England, term for drain cock.

TAPPET: The adjusting screw for varying the clearance between the valve stem and the cam. May be built into the valve lifter in an engine or may be installed in the rocker arm on an overhead valve engine.

T.D.C.: Top dead center.

TEMPER: To change the physical characteristics of metal by the application of heat.

TENSION: Effort devoted towards elongation or "stretching" of a material.

TERMINAL: In automotive electrical work, a junction point whereat connections are made, such as the terminal fitting on the end of a wire.

T-HEAD ENGINE: An engine design wherein the inlet valves are placed on one side of the cylinder and the exhaust valves placed on the other.

THERMAL EFFICIENCY: A gallon of fuel contains a certain amount of potential energy in the form of heat when burned in the combustion chamber. Some of this heat is lost and some is converted into power. The thermal efficiency is the ratio of work accomplished compared to the total quantity of heat contained in the fuel.

THERMOSTAT: A heat controlled valve used in the cooling system of an automobile engine to regulate the flow of water between the cylinder block and the radiator or used in the electrical circuit of the car heating system to control the amount of heat supplied to the passengers.

THERMO-SYPHON: A method of cooling an engine which utilizes the difference in specific gravity of hot and cold water. No pump is used, but the water passages are larger than in the pump circulation system.

THIRD BRUSH: As used on automobile generators, this is an auxiliary brush placed on the commutator in such relation to the main brushes that it serves to control the current output of the generator.

THROW: With reference to an automobile engine, usually the distance from the center of the crankshaft main bearing to the center of the connecting rod journal.

"TICK-OVER": English term for engine idle speed.

TIE ROD: The rod serving to connect the steering spindle arms on opposite sides of the vehicle.

TIMER: Refers to the ignition distributor which times or supplies a spark to the spark plugs at the proper instant.

TIMING CHAIN: Chain used to drive camshaft and accessory shafts of an engine.

TIMING GEARS: Any group of gears which are driven from the engine crankshaft to cause the valves, ignition and other engine driven apparatus to operate at the desired time during the engine cycle.

TOE: The inside or smaller half of a gear tooth; also see Brake Shoe Toe.

TOE-IN: Vehicle wheels are adjusted so that the front of the wheels are closer together than the rear of the wheels. This is done to facilitate steering of the vehicle. The difference in measurement between the front of the wheels and the rear of the wheels is known as the toe-in.

TOLERANCE: A permissible variation between the two extremes of a specification of dimensions.

TOMMY BAR: English term for "T" handle.

TOP UP: English term for fill up.

TORQUE: An effort devoted toward twisting or turning.

TORQUE CONVERTER: A turbine device utilizing a rotary pump, one or more reactors and a driven circular turbine or vane whereby power is transmitted from a driving to a driven member by hydraulic action.

TORQUE WRENCH: A special wrench with a built-in indicator to measure the applied force.

TRACTOR FUEL: A fuel similar to kerosene or like Diesel oil and which is considerably less volatile than gasoline.

"TRAMP": A term used to describe an oscillating motion of a solid axle wherein the wheels on opposite sides rise and fall alternately.

TRANSAXLE: Type of construction in which the transmission and differential are combined in one unit.

TRANSFORMER: An electrical device, such as a high tension coil which transforms or changes the characteristics of an electrical current.

TRANSMISSION: A system of trading speed for power or vice versa, such as gearing or torque conversion. As used on automobiles, includes various devices and combinations for changing the ratio between the engine revolutions and the driving wheel revolutions.

TROUBLE SHOOTING: As used in connection with automotive service, refers to a process of diagnosing or deducing the source of the trouble or troubles from observation and testing.

TUNE-UP: With reference to an automobile engine, a process of accurate and careful adjustments to obtain the utmost in performance.

TURBINE: A series of blades located on a wheel at an angle with the shaft against which fluids or gases are impelled to impart rotary motion to the shaft.

TURBULENCE: A disturbed or disordered, irregular motion of fluids or gases.

TURNING RADIUS: The diameter of a circle within which a vehicle can be turned around.

TWO CYCLE ENGINE: An engine design permitting a power stroke once for each revolution of the crankshaft.

UNDERCOATING: Refers to the spraying of a plastic material on the exposed undersections of an automobile to retard corrosion and deaden noise.

UNIT POWER PLANT:. An assembly wherein the engine, clutch and transmission are combined in one unit.

UNIVERSAL JOINT: A connection for transmitting power from a driving to a driven shaft through an angle.

UNSPRUNG WEIGHT: Unsprung weight includes wheels, axles, etc. that are not supported by the car springs. Sprung weight is a term used to describe all parts of an automobile that are supported by the car springs, such as the frame, engine, body, etc.

UP-DRAFT: Used to describe a carburetor type wherein the mixture flows upward to the engine.

UPPER CYLINDER LUBRICATION: A method of introducing a lubricant into the fuel or intake manifold in order to permit lubrication of the upper cylinder, valve guides, etc.

UPSET: To compress endwise causing an increase in diameter.

VACUUM: A perfect vacuum has not been created as this would involve an absolute lack of pressure. The term is ordinarily used to describe a partial vacuum, that is, a pressure less than atmospheric pressure; in other words a suction.

VACUUM CONTROL: In an ignition distributor, a diaphragm attached to the spark advance which is controlled by the changing of vacuum in the intake manifold.

VACUUM GAUGE: An instrument designed to measure the degree of vacuum existing in a chamber.

VALVE: Used in great variety in automobiles and of many types. A valve is a device for opening and sealing an aperture.

VALVE CLEARANCE: The air gap allowed between the end of the valve stem and the valve lifter or rocker arm to compensate for expansion due to heat.

VALVE FACE: That part of a valve which mates with and rests upon a seating surface.

VALVE GRINDING: Also called valve lapping. A process of lapping or mating the valve seat and valve face usually performed with the aid of an abrasive.

VALVE HEAD: The portion of the valve upon which the valve face is machined.

VALVE-IN-HEAD ENGINE: Same as overhead valve engine.

VALVE KEY OR VALVE LOCK: The key, washer, or other device which holds the valve spring cup or washer in place on the valve stem.

VALVE LIFTER: A push rod or plunger placed between the cam and the valve on an engine; is often adjustable to vary the length of the unit.

VALVE MARGIN: On a poppet valve the space or rim between the surface of the head and the surface of the valve face.

VALVE OVERLAP: An interval expressed in degrees where both valves of an automobile engine cylinder are open at the same time.

VALVE SEAT: The matched surface upon which the valve face rests.

VALVE SPRING: A spring attached to a valve to return it to the seat after it has been released from the lifting or opening means.

VALVE STEM: That portion of a valve which rests within a guide.

VALVE STEM GUIDE: A bushing or hole in which the valve stem is placed which allows lateral motion only.

VANES: Any plate, blade or the like attached to an axis and moved by or in air or a liquid.

VAPORIZER: A device for transforming or helping to transform a liquid into a vapor; often includes the application of heat.

VAPOR LOCK: A condition wherein the fuel boils in the fuel system forming bubbles which retard or stop the flow of fuel to the carburetor.

VAPOR PRESSURE: The pressure developed over a liquid in a closed vessel depending upon the liquid and the temperature.

VAPOR WITHDRAWAL: A system of piping and connections to operate an engine directly on the vapor taken from the top of an L.P.G. tank.

VENTURI: Two tapering streamlined tubes joined at their small ends so as to reduce the internal diameter.

VIBRATION DAMPER: A device to reduce the torsional or twisting vibration which occurs along the length .of the crankshaft used in multiple cylinder engines; also known as a harmonic balancer.

VISCOSIMETER: An instrument for determining the viscosity of an oil by passing a certain quantity at a definite temperature through a standard size orifice or port. The time required for the oil to pass through expressed in seconds gives the viscosity.

VISCOSITY: The resistance to flow or adhesiveness characteristics of an oil.

VOLATILITY: The tendency for a fluid to evaporate rapidly or pass off in the form of vapor. For example, gasoline is more volatile than kerosene as it evaporates at a lower temperature.

VOLT: A unit of electrical force which will cause a current of one ampere to flow through a resistance of one ohm.

VOLTAGE REGULATOR: An electrical device for controlling or regulating voltage.

VOLTMETER: An instrument for measuring the voltage in an electrical circuit.

VOLUME: The measure of space expressed as cubic inches, cubic feet, etc.

VOLUMETRIC EFFICIENCY: A combination between the ideal and actual efficiency of an internal combustion engine. If the engine completely filled each cylinder on each induction stroke the volumetric efficiency of the engine would be 100 per cent. In actual operation, however, volumetric efficiency is lowered by the inertia of the gases, the friction between the gases and the manifolds, the temperature of the gases and the pressure of the air entering the carburetor. Volumetric efficiency is ordinarily increased by the use of large valves, ports and manifolds and can be further increased with the aid of a supercharger.

VORTEX: A whirling movement or mass of liquid or air.

"WANDERING": A condition wherein the steering wheels of an automobile tend to turn slowly in first one direction and the other thus interferring with directional control or stability.

WATER COLUMN: A reference term used in connection with a Manometer.

WATT: A measuring unit of electrical power. It is obtained by multiplying amperes by volts.

WEIGHT TRANSFER EFFECT: As the center of gravity of the vehicle is located above the centers of wheel rotation, a sudden stoppage of the vehicle tends to cause the center of gravity to move forward, thus throwing more weight on the front wheels and less on the rear wheels.

WELDING: To join two pieces of metal by heating them to the fusion or melting point.

WHEEL CYLINDERS: The hydraulic cylinders in a braking system which are actuated by hydraulic pressure to force the brake lining into contact with the braking drum or disk.

WHITE METAL: An alloy of tin, lead and antimony having a low melting point and a low coefficient of friction.

WINDSCREEN: English name for windshield.

WING: English name for fender.

WIRING DIAGRAM: A detailed drawing of all wiring, connections and units connected together in an electrical circuit.

WORM GEAR: A shaft having an extremely coarse thread which is designed to operate in engagement with a toothed wheel, as a pair of gears.

WRINGING-FIT: Wherein the clearance is less than for a running or sliding fit and the shaft will enter the hole by means of twisting and pushing by hand.

WRIST PIN: The journal for the bearing in the small end of an engine connecting rod which also passes through piston walls; also known as a piston pin.

USEFUL CHARTS AND TABLES

DECIMAL EQUIVALENT OF THE NUMBERS OF TWIST DRILL AND STEEL WIRE GAUGE

No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals	No.	Size of No. in Decimals
1	.2280	17	.1730	33	.1130	49	.0730	65	.0350
2	.2210	18	.1695	34	.1110	50	.0700	66	.0330
3	.2130	19	.1660	35	.1100	51	.0670	67	.0320
4	.2090	20	.1610	36	.1065	52	.0635	68	.0310
5	.2055	21	.1590	37	.1040	53	.0595	69	.0292
6	.2040	22	.1570	38	.1015	54	.0550	70	.0280
7	.2010	23	.1540	39	.0995	55	.0520	71	.0260
8	.1990	24	.1520	40	.0980	56	.0465	72	.0250
9	.1960	25	.1495	41	.0960	57	.0430	73	.0240
10	.1935	26	.1470	42	.0935	58	.0420	74	.0225
11	.1910	27	.1440	43	.0890	59	.0410	75	.0210
12	.1890	28	.1405	44	.0860	60	.0400	76	.0200
13	.1850	29	.1360	45	.0820	61	.0390	77	.0180
14	.1820	30	.1285	46	.0810	62	.0380	78	.0160
15	.1800	31	.1200	47	.0785	63	.0370	79	.0145
16	.1770	32	.1160	48	.0760	64	.0360	80	.0135

LUBRICANTS FOR CUTTING TOOLS

Material	Turning	Chucking	Drilling Milling	Reaming	Tapping
Tool Steel	Dry or Oil	Oil or Soda Water	Oil	Lard Oil	Oil
Soft Steel	Dry or Soda Water	Soda Water	Oil or Soda Water	Lard Oil	Oil
Wrought Iron	Dry or Soda Water	Soda Water	Oil or Soda Water	Lard Oil	Oil
Cast Iron	Dry	Dry	Dry	Dry	Oil
Brass	Dry	Dry	Dry	Dry	Oil
Copper	Dry	Oil	Oil	Mixture	Oil
Babbitt	Dry	Dry	Dry	Dry	Oil
Glass		Turpentine or Kerosene			

Mixture is 1/3 Crude Petroleum, 2/3 Lard Oil; when two lubricants are mentioned, the first is preferable.

CALCULATING PISTON DISPLACEMENT

The area of the head of the piston in square inches, times the number of inches in the stroke, times the number of cylinders, is the engine displacement in cubic inches. The formula is:

$$D^2 \times .7854 \times L \times N = \text{Displacement in Cu. In.}$$

Here D equals piston diameter or cylinder bore.
L is the stroke in inches. N is the number of cylinders.

HIGH TEMPERATURES JUDGED BY COLOR AND COLORS FOR TEMPERING

Degrees Centigrade	Degrees Fahrenheit	High Temperatures Judged by color	Degrees Centigrade	Degrees Fahrenheit	Colors for Tempering
400	752	Red heat, visible in the dark	221.1	430	Very pale yellow
474	885	Red heat, visible in the twilight	226.7	440	Light yellow
525	975	Red heat, visible in the daylight	232.2	450	Pale straw-yellow
581	1077	Red heat, visible in the sunlight	237.8	460	Straw-yellow
700	1292	Dark red	243.3	470	Deep straw-yellow
800	1472	Dull cherry-red	248.9	480	Dark yellow
900	1652	Cherry-red	254.4	490	Yellow-brown
1000	1832	Bright cherry-red	260.0	500	Brown-yellow
1100	2012	Orange-red	265.6	510	Spotted red-brown
1200	2192	Orange-yellow	271.1	520	Brown-purple
1300	2372	Yellow-white	276.7	530	Light purple
1400	2552	White welding heat	282.2	540	Full purple
1500	2732	Brilliant white	287.8	550	Dark purple
1600	2912	Dazzling white (bluish-white)	293.3	560	Full blue
			298.9	570	Dark blue

MELTING POINT OF METALS

Metal	Degrees Fahrenheit	Metal	Degrees Fahrenheit
Aluminum	1220.4	Solder (50-50)	*415.0
Copper	1981.4	Solder (63% tin--37% lead)	360.0
Iron	2795.0	Solder (40% tin--60% lead)	*459.0
Lead	621.2	Tin	449.4
Platinum	3224.0	Tungsten	6120.0
Silver	1761.0	Zinc	787.2

*First melting point 360°.

FIGURING PULLEY SIZES AND RPM

To Find:

RPM of Driven Pulley	Multiply diameter of driving pulley by its rpm and divide by diameter of driven pulley.
Diameter of Driven Pulley	Multiply diameter of driving pulley by its rpm and divide by rpm of driven pulley.
RPM of Driving Pulley	Multiply diameter of driven pulley by its rpm and divide by diameter of driving pulley.
Diameter of Driving Pulley	Multiply diameter of driven pulley by its rpm and divide by rpm of driving pulley.

NOMINAL TORQUE FOR TIGHTENING STUD NUTS AND BOLTS

Stud or Bolt Diameter	Tightening Torque	
	In. Lbs.	Ft. Lbs.
1/4	55 - 85	4.5 - 7
5/16	110 - 165	9 - 14
3/8	190 - 285	16 - 24
7/16	295 - 445	25 - 37
1/2	450 - 680	38 - 57
9/16	640 - 970	53 - 81
5/8	880 - 1300	73 - 110

THE METRIC SYSTEM OF MEASUREMENT
MEASURES OF LENGTH

1 Millimeter (mm.) = ...0.03937079 inch, or about 1/25 inch
10 Millimeters = 1 Centimeter (cm.) = ...0.3937079 inch
10 Centimeters = 1 Decimeter (dm.) =..3.937079 inch
10 Decimeters = 1 Meter (m.) =...39.37079 inches, 3.2808992 feet, or 1.09361 yards
10 Meters = 1 Decameter (Dm.) = ...32.808992 feet
10 Decameters = 1 Hectometer (Hm.) = ...19.927817 rods
10 Hectometers = 1 Kilometer (Km.) = ...1093.61 yards, or 0.6213824mile
10 Kilometers = 1 Myriameter (Mm.) = ...6.213824 miles

1 inch = 2.54 cm., 1 foot = 0.3048 m., 1 yard = 0.9144 m., 1 rod = 0.5029 Dm., 1 mile = 1.6093 Km.

MEASURES OF WEIGHT

1 Gramme (g.) = 15.4324874 gr. Troy, or 0.03215 oz. Troy, or 0.03527398 oz. avoirdupois
10 Grammes = 1 Decagramme (Dg.) = ...0.3527398 oz. avoirdupois
10 Decagrammes = 1 Hectogramme (Hg.) =................................3.527398 oz. avoirdupois
10 Hectogrammes = 1 Kilogramme (Kg.) = ...2.20462125 lbs.
1000 Kilogrammes = 1 Tonne (T.) = 2204.62125 lbs., or 1.1023 tons of 2000 lbs., or 0.9842 ton of 2240 lbs., or 19.68 cwts.
1 grain = 0.0648 g., 1 oz. avoirdupois = 28.35 g., 1 lb. = 0.4536 Kg., 1 ton (2000 lbs.) = 0.9072 T., 1 ton (2240 lbs.) = 1.016 T., or 1016 Kg.

MEASURES OF CAPACITY

1 Liter (l.) = 1 cubic decimeter = 61.0270515 cubic in., or 0.03531 cu. ft. or 1.0567 liquid qts., or 0.908 dry qt., or 0.26417 Amer. gal.
10 Liters = 1 Decaliter (Dl.) = ...2.6417 gal., or 1.135 pk.
10 Decaliters = I Hectoliter (Hl.) = ...2.8375 bu.
10 Hectoliters = 1 Kiloliter (Kl.) = 61027.0515 cu. in. or 28.375 bu.
1 cu. foot = 28.3171., 1 gallon (American) = 3.7851., 1 gallon (British) = 4.5431.

METRIC CONVERSION TABLE MILLIMETERS TO INCHES

Millimeters	Inches	Millimeters	Inches	Millimeters	Inches	Millimeters	Inches
.01	.0003937	.11	.00433	.21	.00827	.31	.01221
.02	.0007874	.12	.00472	.22	.00866	.32	.01259
.03	.00118	.13	.00512	.23	.00905	.33	.01299
.04	.00157	.14	.00551	.24	.00945	.34	.01338
.05	.00197	.15	.00591	.25	.00984	.35	.01378
.06	.00236	.16	.00630	.26	.01024	.40	.01575
.07	.00276	.17	.00669	.27	.01063	.45	.01772
.08	.00315	.18	.00708	.28	.01102	.50	.01968
.09	.00354	.19	.00748	.29	.01141	1.00	.03937
.10	.00394	.20	.00787	.30	.01181		

RULES RELATIVE TO THE CIRCLE, ETC.

To Find Circumference--
Multiply diameter by 3.1416 or divide diameter by 0.3183
To Find Diameter--
Multiply circumference by 0.3183 or divide circumference by 3.1416
To Find Radius--
Multiply circumference by 0.15915 or divide circumference by 6.28318
To Find the Area of a Circle--
Multiply circumference by one-quarter of the diameter
Or multiply the square of diameter by 0.7854
Or multiply the square of circumference by .07958
Or multiply the square of 1/2 diameter by 3.1416
To Find the Surface of a Sphere or Globe--
Multiply the diameter by the circumference
Or multiply the square of diameter by 3.1416
Or multiply four times the square of radius by 3.1416

ELECTRICAL CALCULATIONS

To Find:

Amperes, divide volts by ohms.
Volts, multiply amperes by ohms.
Ohms, divide volts by amperes.
Watts, multiply volts by amperes (one kilowatt is 1000 watts).
Horsepower, divide watts by 746 or kilowatts by 0.746. One kilowatt equals 1.340 horsepower.

APPROXIMATE WEIGHT OF VARIOUS LIQUIDS

Liquid	Pounds Per Gallon
Alcohol	6.576
Gasoline	6.042
Kerosene	6.668
Oil (lubricating)	7.584
Water	8.335

INDIANAPOLIS RACE RESULTS

Year	Driver	Car	Time	M.P.H.
1911	Ray Harroun	Marmon Wasp	6:42:08	74.59
1912	Joe Dawson	National	6:21:06	78.72
1913	Jules Goux	Peugeot	6:35:05:00	75.933
1914	Rene Thomas	Delage	6:03:45	82.47
1915	Ralph DePalma	Mercedes	5:33:55.51	89.84
1916	Dario Resta	Peugeot	3:34:17	84.00
	(300-mile race)			
1919	Howard Wilcox	Peugeot	5:40:42.87	88.05
1920	Gaston Chevrolet	Monroe	5:38:32.00	88.62
1921	Tommy Milton	Frontenac	5:34:44.65	89.62
1922	James A. Murphy	Murphy Special	5:17:30.79	94.48
1923	Tommy Milton	H.C.S. Special	5:29:50.17	90.95
1924	L. L. Corum and Joe Boyer	Duesenberg Special	5:05:23.51	98.23
1925	Peter DePaolo	Duesenberg Special	4:56:39.46	101.13
1926	Frank Lockhart	Miller Special	4:10:14.95	95.904
	(Race called at 400 miles because of rain)			
1927	George Souders	Duesenberg	5:07:33.08	97.545
1928	Louis Meyer	Miller Special	5:01:33.75	99.482
1929	Ray Keech	Simplex Piston Ring	5:07:25.42	97.585
1930	Billy Arnold	Miller Hartz Special	4:58:39.72	100.448
1931	L. Schneider	Bowes Seal Fast Spl.	5:10:27.93	96.629
1932	Fred Frame	Miller Hartz Special	4:48:03.79	104.144
1933	Louis Meyer	Tydol Special	4:48:00.75	104.162
1934	Wm. Cummings	Boyle Products Spl.	4:46:05.20	104.863
1935	Kelly Petillo	Gilmore Speedway Spl.	4:42:22.71	106.240
1936	Louis Meyer	Ring Free Special	4:35:03.39	109.069
1937	Wilbur Shaw	Shaw Gilmore Spl.	4:24:07.80	113.580
1938	Floyd Roberts	Burd Piston Ring Spl.	4:15:58.40	117.200
1939	Wilbur Shaw	Boyle Special	4:20:47.39	115.035
1940	Wilbur Shaw	Boyle Special	4:22:31.17	114.277
1941	Mauri Rose and Floyd Davis	Noc-Out Hose Clamp Sp.	4:20:36.24	115.117
1946	George Robson	Thorne Engineer. Spl.	4:21:26.70	114.820
1947	Mauri Rose	Blue Crown Spk. Plg. Sp.	4:17:52.17	116.338
1948	Mauri Rose	Blue Crown Spk. Plg. Sp.	4:10:23.33	119.814
1949	Bill Holland	Blue Crown Spk. Plg. Sp.	4:07:15.97	121.327
1950	Johnny Parsons	Kurtis-Kraft	2:46:55.97	124.002
	(Race called at 345 miles because of rain)			
1951	Lee Wallard	Belanger Special	3:57:38.05	126.244
1952	Troy Ruttman	Agajanian Special	3:52:41.88	128.922
1953	Bill Vukovich	Fuel Injection Spl.	3:53:01.69	128.740
1954	Bill Vukovich	Fuel Injection Spl.	3:49:17.27	130.840
1955	Bob Sweikert	John Zink Special	3:53:59.13	128.209
1956	Pat Flaherty	John Zink Special	3:53:28.84	128.490
1957	Sam Hanks	Belond Exhaust Spl.	3:41:14.25	135.601
1958	Jimmy Bryan	Belond AP Special	3:44:13.80	133.791
1959	Rodger Ward	Leader Card 500 Rdstr.	3:40;49.20	135.857
1960	Jim Rathmann	Ken-Paul Special	3:36:11.36	138.767
1961	A. J. Foyt	Bowes Seal Fast Spl.	3:35:37.49	139.130
1962	Roger Ward	Leader Card Spl.	3:33:50.38	140.292

Official Mechanical and

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MAKE AND MODEL	Wheelbase	Tire Size	Number of Cylinders, Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower @ R.P.M.	H. P. Per Cubic Inch Displacement	No. of Main Bearings	Operating Tappet Clearance	
										Intake	Exhaust
Buick 40	121 1/2	7.60/15	8-3 3/16 x 4 1/8	263.3	IO	6.60	120@3600	.456	5	.015	.015
" 50	121 1/2	7.60/15	8-3 3/16 x 4 1/8	263.3	IO	6.90	124@3600	.471	5	h	h
" 70	126 13/64	8.00/15	8-3 7/16 x 4 5/16	320.2	IO	7.20	152@3600	.475	5	h	h
Cadillac 61	122	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	7.50	160@3800	.484	5	h	h
" 62	126	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	7.50	160@3800	.484	5	h	h
" 60	130	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	7.50	160@3800	.484	5	h	h
" 75	146 3/4	8.20/15	8-3 13/16 x 3 5/8	331.0	VO	7.50	160@3800	.484	5	h	h
Chevrolet JJ,JK	115	6.70/15	6-3 1/2 x 3 3/4	216.5	IO	6.60	92@3400	.425	4	.006H	.013H
" 2100	115	6.70/15	6-3 9/16 x 3 15/16	235.5	IO	6.70	105@3600	.446	4	h	h
Chrysler C-51	125 1/2	7.60/15	6-3 7/16 x 4 1/2	250.6	IL	7.00	116@3600	.463	4	.008H	.010H
" C-52,54	131 1/2	8.20/15	8-3 13/16 x 3 5/8	331.1	VO	7.50	180@4000	.544	5	h	h
Crosley CD,VC	80	4.50/12	4-2 1/2 x 2 1/4	44.0	IO	8.00	26.5@5400	.602	5	.005C	.008C
De Soto S-15	125 1/2	7.60/15	6-3 7/16 x 4 1/2	250.6	IL	7.00	116@3600	.463	4	.008H	.010H
Dodge D-41	115	6.70/15	6-3 1/4 x 4 5/8	230.2	IL	7.00	103@3600	.447	4	.008H	.010H
" D-42	123 1/2	7.10/15	6-3 1/4 x 4 5/8	230.2	IL	7.00	103@3600	.447	4	.008H	.010H
Ford 1HA	114	6.00/16	6-3.3 x 4.4	225.9	IL	6.80	95@3600	.421	4	.014C	.018C
" 1BA	114	6.00/16	8-3 3/16 x 3 3/4	239.4	VL	6.80	100@3600	.418	3	.014C	.018C
Frazer 515,516	123 1/2	7.10/15	6-3 5/16 x 4 3/8	226.2	IL	7.30	115@3650	.508	4	.014C	.014C
Henry J 513	100	5.90/15	4-3 1/8 x 4 3/8	134.2	F	7.00	68@4000	.506	3	.016H	.016H
" " 514	100	5.90/15	6-3 1/8 x 3 1/2	161.0	IL	7.00	80@3800	.446	4	.016H	.016H
Hudson 4A	119 7/8	7.10/15	6-3 9/16 x 3 7/8	232.0	IL	6.70	112@4000	.483	4	.008H	.010H
" 5A,6A	123 7/8	7.10/15	6-3 9/16 x 4 3/8	262.0	IL	6.70	123@4000	.469	4	.008H	.010H
" 7A	123 7/8	7.10/15	6-3 13/16 x 4 1/2	308.0	IL	7.20	145@3800	.470	4	.008H	.010H
" 8A	123 7/8	7.10/15	8-3 x 4 1/2	254.0	IL	6.70	128@4200	.504	5	.008H	.010H
Kaiser 511,512	118 1/2	6.70/15	6-3 5/16 x 4 3/8	226.2	IL	7.30	115@3650	.508	4	.014C	.014C
Lincoln 1EL	121	8.00/15	8-3 1/2 x 4 3/8	336.7	VL	7.00	154@3600	.457	3	.000	.000
" 1EH	125	8.20/15	8-3 1/2 x 4 3/8	336.7	VL	7.00	154@3600	.457	3		
Mercury 1CM	118	7.10/15	8-3 3/16 x 4	255.4	VL	6.80	112@3600	.439	3	.012C	
Nash 5110	100	5.90/15	6-3 1/8 x 3 3/4	172.6	IL	7.25	82@3800	.475	4	.015H	.015H
" 5140	112	6.40/15	6-3 1/8 x 4	184.0	IL	7.00	85@3800	.462	4	.015H	.015H
" 5160	121	7.10/15	6-3 3/8 x 4 3/8	234.8	IO	7.30	115@3400	.489	7	.015H	.018H
Oldsmobile 88	119 1/2	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	7.50	135@3600	.445	5	h	h
" 98	122	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	7.50	135@3600	.445	5	h	h
Packard 200	122	7.60/15	8-3 1/2 x 3 3/4	288.0	IL	7.00	135@3600	.469	5	.007H	.010H
" 300	127	8.00/15	8-3 1/2 x 4 1/4	327.0	IL	7.00	150@3600	.459	5	h	h
" 400	127	8.00/15	8-3 1/2 x 4 1/4	327.0	IL	7.80	155@3600	.474	9	h	h
Plymouth P-22	111	6.40/15	6-3 1/4 x 4 3/8	217.8	IL	7.00	97@3600	.445	4	.008H	.010H
" P-23	118 1/2	6.70/15	6-3 1/4 x 4 3/8	217.8	IL	7.00	97@3600	.445	4	.008H	.010H
Pontiac 1951-25	120	7.10/15	6-3 9/16 x 4	239.2	IL	6.50	96@3400	.402	4	.012H	.012H
" 1951-27	120	7.10/15	8-3 3/8 x 3 3/4	268.4	IL	6.50	116@3600	.431	5	.012H	.012H
Studebaker 10-G	115	6.40/15	6-3 x 4	169.6	IL	7.00	85@4000	.501	4	.016C	.016C
" H	115-119	7.10/15	8-3 3/8 x 3 1/4	232.6	VO	7.00	120@4000	.515	5	.015H	.015H
Willys 473-SD	104	6.50/15	4-3 1/8 x 4 3/8	134.2	F	7.40	72@4000	.536	3	.018C	.012C
" 673-SD	104	6.70/15	6-3 1/8 x 3 1/2	161.0	IL	6.90	75@4000	.466	4	.016H	.016H

ABBREVIATIONS:

A - American Bosch
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
B - Before Top Center
C - Carter Carburetor
CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug

CS - Coil Spring
CaS - Cantilever Spring
D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco-Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs
E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
F - Ford

FA - Ford or American Bosch
FE - Full Elliptic Leaf Spring
FH - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley Carburetor
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement
Hy - Hydramatic Transmission
hy - Hydraulic Tappets
IC - Independent Suspension W/Coil Spring

Tuneup Specifications

Intake Tappet Clearance For Valve Timing	Intake Valve Opens — Degrees	Make of Carburetor	Make of Ignition System	Breaker Point Gap	Breaker Point Opens — Degrees	Spark Plug		Spark Plug Gap	Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Caster Degrees	Camber Degrees	Toe-In	King-Pin Inclination	Capacity Cooling System	Capacity Crankcase	Lowest Price Four-Door Sedan	Weight Lowest Price Four-Door Sedan
						Make	Model													
	13B	C/S	DR	.015	4B	AC	46x	.025	3/TQ	TT	IC	CS	5/8	1/8	3/32	4 1/4	12	6 1/2	$1810.	3605
h	13B	C/S	DR	.015	4B	AC	46x	.025	3/TQ	TT	IC	CS	5/8	1/8	3/32	4 1/4	12	6 1/2	2058.	3845
h	14B	C/S	DR	.015	6B	AC	46x	.025	TQ	TT	IC	CS	5/8	1/8	3/32	4 1/4	18	8	2568.	4240
.001	24B	C	DR	.016	5B	AC	46-5	.035	3/Hy	Ex	IC	Se	0	0	1/8	5 5/6	18	5	2690.	3890
.001	24B	C	DR	.016	5B	AC	46-5	.035	Hy	Ex	IC	Se	0	0	1/8	5 5/6	18	5	3040.	4040
.001	24B	C	DR	.016	5B	AC	46-5	.035	Hy	Ex	IC	Se	0	0	1/8	5 5/6	18	5	3565.	4200
.001	24B	C	DR	.016	5B	AC	46-5	.035	3/Hy	Ex	IC	Se	0	0	1/8	5 5/6	18	5	4480.	4690
	1B	R	DR	.021	5B	AC	46-5	.035	3	TT	IC	Se	0	0	1/32	4 1/4	15	5 1/2	1355.	3130
h	16B	R	DR	.021	5B	AC	46-5	.035	TQ	TT	IC	Se	0	0	1/32	4 1/4	15	5 1/2	1430.	3140
.014	12B	C	AL	.020	2B	AL	AR8	.035	3/Fm	Ex	IC	Se	-2	0	1/32	5	15	5	2021.	3665
.000	15B	C	AL	.016	TC	AL	AAR6	.035	TQ	Ex	IC	Se	-2	0	1/32	5	15	5	2631.	4260
	5B	Til	AL	.020	12B	CH	J-8	.025	3	Ex	Se	Se	7 1/2	2	3/64	6 1/2	4	2 3/4	818.	1363
.014	12B	C	AL	.020	2B	AL	AR8	.035	3/Fm	Ex	IC	Se	-2	0	1/32	5	15	5	1881.	3570
.014	8B	S	AL	.020	2B	AL	AR8	.035	3/Fm	Ex	IC	Se	-1	0	1/32	5	14	5	1750.	3415
.014	8B	S	AL	.020	2B	AL	AR8	.035	3/Fm	Ex	IC	Se	-1	0	1/32	5	14	5	1825.	3415
.014	11B	Ho	F	.025	TC	CH	H-10	.031	3/TQ/30	Ex	IC	Se	-1/4	1/2	3/32	5 1/4	14	5	1368.	3075
.014	5B	F	F	.015	2B	CH	H-10	.031	3/TQ/30	Ex	IC	Se	-1/4	1/2	3/32	5 1/4	17 1/3	5	1438.	3115
.014	10B	C	AL	.020	4B	AL	A-5G	.032	3/Hy/30	Ex	IC	Se	0	3/8	1/32	4 3/4	13	5 1/2	2221.	3535
.020	9B	C	AL	.020	TC	AL	AN7	.030	3/30	Ex	IC	Se	0	5/8	7/64	4 1/2	10 13/16	4	1219.	2300
.020	5B	C	AL	.020	TC	AL	AN7	.030	3/30	Ex	IC	Se	0	5/8	7/64	4 1/2	9	5	1343.	2325
	7°18'	C	AL	.020	TC	CH	H-8	.032	3/30/E-V	Ex	IC	Se	1	1	1/32	3 3/5	18 1/2	7 1/2	1940.	3510
	7°18'	C	AL	.020	TC	CH	H-8	.032	3/30/E-V	Ex	IC	Se	1	1	1/32	3 3/5	18 1/2	7 1/2	2074.	3590
	7°18'	C	AL	.020	TC	CH	H-8	.032	3/30/Hy	Ex	IC	Se	1	1	1/32	3 3/5	18 1/2	7 1/2	2248.	3655
	10°40'	C	AL	.017	TC	CH	H-8	.032	3/30/Hy	Ex	IC	Se	1	1	1/32	3 3/5	18 1/2	8	2330.	3675
.014	10B	C	DR	.020	4B	AL	A-5	.032	3/30/Hy	Ex	IC	Se	0	1/2	1/8	5 1/2	13 1/2	5 1/2	1983.	3150
.006	5B	Ho	F	.015	4B	CH	H-10	.031	3/30/Hy	Ex	IC	Se	-3/4	3/8	1/8	5	34 1/2	6 1/2	2395.	4180
.006	5B	Ho	F	.015	4B	CH	H-10	.031	3/30/Hy	Ex	IC	Se	-3/4	3/8	1/8	5	34 1/2	6 1/2	3025.	4490
.015	10B	Ho	F	.015	2B	CH	H-10	.031	3/30/TQ	Ex	IC	Se	-3/4	3/8	1/8	5	22 1/4	6	1895.	3550
.019	6B	C	DR	.021	TC	AL	A-5	.030	3/30	Ex	IC	Se	1	1/2	3/32	8	11	5	1623.	
.019	6B	C	DR	.021	TC	AL	A-5	.030	3/30/Hy	Ex	IC	Se	1/4	0	1/8	8 1/2	15	5	1696.	2965
.022	8 1/2	C	DR	.021	TC	AL	A-5	.030	3/30/Hy	Ex	IC	Se	1/4	0	1/8	8 1/2	18	6	2022.	3350
h	13 1/2	C/R	DR	.016	2 1/2B	AC	46-5	.030	3/Hy	Ex	IC	Se	-3/8	1/4	3/32	4 1/2	21 1/2	5	1840.	3542
h	13 1/2	C/R	DR	.016	2 1/2B	AC	46-5	.030	3/Hy	Ex	IC	Se	-3/8	1/4	3/32	4 1/2	21 1/2	5	2235.	3787
.012	15B	C	AL/DR	.015	6B	AC	46-5	.028	3/TQ/30	Ex	IC	Se	-1	0	1/32	5 5/6	20	7	2166.	3600
h	15B	C	AL/DR	.015	6B	AC	46-5	.028	3/TQ/30	Ex	IC	Se	-1	0	1/32	5 5/6	20	7	2716.	3930
h	15B	C	AL/DR	.015	6B	AC	46-5	.028	TQ	Ex	IC	Se	-1	0	1/32	5 5/6	20	7	3283.	4115
.014	12B	C	AL	.019	2B	AL	AR-8	.035	3	Ex	IC	Se	0	0	1/32	5 1/2	13	5	1465.	3110
.014	12B	C	AL	.019	2B	AL	AR-8	.035	3	Ex	IC	Se	0	0	1/32	5 1/2	13	5	1540.	3115
.015	5B	R	DR	.022	6B	AC	45	.026	3/Hy	Ex	IC	Se	-1/2	0	1/32	5	18 5/16	6	1627.	3273
.015	5B	C	DR	.016	6B	AC	45	.026	3/Hy	Ex	IC	Se	-1/2	0	1/32	5	19 17/32	6	1692.	3363
.020	15B	C	AL	.020	2B	CH	J-7	.025	3/30/TQ	Ex	IC	Se	-1 1/4	1/2	3/32	5 1/4	10	5	1465.	2690
.020	11B	S	DR	.016	8B	CH	H-8	.035	3/30/TQ	Ex	IC	Se	-1 1/4	1/2	3/32	5 1/4	17 1/4	6	1715.	3070
.026	9B	C	AL	.020	TC	CH	J-7	.030	3/30	Ex	IC	Se	1	1	3/32	5	11	4		
.020	5B	Z	AL	.020	TC	CH	J-7	.030	3/30	Ex	IC	Se	1	1	3/32	5	9	5		

IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves
J - Johnson Carburetor
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders
R - Rochester Carburetor
S - Stromberg Carburetor
SV - Sliding Valves

Se - Semi-elliptic Springs
Sch - Schebler Carburetor
Ste - Stewart Carburetors
TA - Torque Arms
TC - Top Center
TH - T-head Engine
TQ - Torque Converter
TT - Torque Tube
Til - Tillotson Carburetor
Tr - Transverse Springs

VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical

1952

MAKE AND MODEL	Wheelbase	Tire Size	Number of Cylinders, Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower @ R.P.M.	H. P. Per Cubic Inch	No. of Main Bearings	Operating Tappet Clearance Intake	Operating Tappet Clearance Exhaust
Allstate "4"	100	5.90/15	4-3 1/8 x 4 3/8	134.2	IL	7.00	68@4000	.507	3	.016C	.016C
Buick Special 40	121 1/2	7.60/15	8-3 3/16 x 4 1/8	263.3	IO	6.60	120@3600	.450	5	.015H	.015H
" Super 50	125 1/2a	7.60/15	8-3 3/16 x 4 1/8	263.3	IO	6.90	124@3600	.470	5	h	h
" Roadmaster 70	126, 130	8.00/15	8-3 7/16 x 4 5/16	320.2	II	7.50	170@3800	.530	5	h	h
Cadillac 60,62,75	126,130a	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	7.50	190@4000	.577	5	h	h
Chevrolet 1500	115	6.70/15	6-3 1/2 x 3 3/4	235.5	IO	6.70	105@3600	.424	4	.006H	.013H
" 2100	115	6.70/15	6-3 9/16 x 3 15/16	235.5	IO	6.70	105@3600	.445	4	h	h
Chrysler 6, C-51	125 1/2	7.60/15	6-3 7/16 x 4 3/4	264.5	IL	7.00	119@3600	.449	4	.008H	.010H
" C52,C54,C55,C53	131 1/2a	8.20/15	8-3 13/16 x 3 5/8	331.1	VO	7.50	180@4000	.543	4	h	h
Crosley CD, VC	80, 85	4.50/12	4-2 1/2 x 2 1/4	44.0	IO	8.00	26@5200	.590	5	.005C	.008C
De Soto S-15	125 1/2	7.60/15	6-3 7/16 x 4 1/2	250.6	IL	7.00	116@3600	.462	4	.008H	.010H
" S-17	125 1/2	7.60/15	8-3 5/8 x 3 11/16	276.1	VO	7.10	160@4400	.579	5	h	h
Dodge	115, 123 1/2	6.70/15	6-3 1/4 x 4 5/8	230.2	IL	7.00	103@3600	.447	4	.008H	.010H
Ford Six	114	6.00/16	6-3 9/16 x 3 3/8	215.3	IO	7.00	101@3500	.470	4	.015	.014C
" V-8	114	6.00/16	8-3 3/16 x 3 3/4	239.4	VL	7.20	110@3800	.420	3	.014C	.018C
Henry J 513	100	5.90/15	4-3 1/8 x 4 3/8	134.2	IL	7.00	68@4000	.506	3	.016C	.016C
" 514	100	5.90/15	6-3 1/8 x 3 1/2	161.0	IFH	7.00	80@3800	.496	4	.016C	.016
Hudson 4B	119 7/8	7.10/15	6-3 9/16 x 3 7/8	232.0	IL	6.70	112@4000	.482	4	.008H	.008H
" 5B,6B	119 7/8a	7.10/15	6-3 9/16 x 4 3/8	262.0	IL	6.70	127@4000	.484	4	.008H	.008H
" 7B	123 7/8	7.10/15	6-3 13/16 x 4 1/2	308.0	IL	7.20	145@3800	.470	4	.008H	.008H
" 8B	123 7/8	7.10/15	8-3 x 4 1/2	254.0	IL	6.70	128@4200	.503	5	.008H	.008H
Kaiser 511,512	118 1/2	6.70/15	6-3 5/16 x 4 3/8	226.2	IL	7.30	115@3650	.508	4	.014C	.014C
Lincoln 1 EL	121	8.00/15	8-3 1/2 x 4 3/8	336.7	VL	7.00	154@3600	.457	3	.000	.000
" 1 EH	125	8.20/15	8-3 1/2 x 4 3/8	336.7	VL	7.00	154@3600	.457	3	.000	.000
Mercury 1 CM	118	7.10/15	8-3 3/16 x 4	255.4	VL	7.20	125@3700	.439	3	.012C	
Nash 5210	100	5.90/15	6-3 1/8 x 3 3/4	172.6	IL	7.25	82@3800	.475	4	.016C	.018C
" 5240	114 1/2	6.70/15	6-3 1/8 x 4 1/4	195.6	IL	7.10	88@3800	.449	4	.015H	.015H
" 5260	121 1/4	7.10/15	6-3 1/8 x 4 3/8	252.6	IO	7.30	120@3700	.475	7	.015H	.018H
Oldsmobile DeL. 88	120	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	7.50	160@3600	.480	5	h	h
" Super 88	120	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	7.50	160@3600	.526	5	h	h
" 98	124	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	7.50	160@3600	.526	5	h	h
Packard 200	122	7.60/15	8-3 1/2 x 3 3/4	288.0	IL	7.00	135@3600	.467	5	.007H	.010H
" 250	122	8.00/15	8-3 1/2 x 4 1/4	327.0	IL	7.00	150@3600	.458	5	A	A
" 300	127	8.00/15	8-3 1/2 x 4 1/4	327.0	IL	7.00	150@3600	.458	5	A	A
" 400	127	8.00/15	8-3 1/2 x 4 1/4	327.0	IL	7.80	155@3600	.474	7	A	A
Plymouth P22	111	6.40/15	6-3 1/4 x 4 3/8	217.8	IL	7.00	97@3600	.445	4	.010H	.010H
" P23	118 1/2	6.70/15	6-3 1/4 x 4 3/8	217.8	IL	7.00	97@3600	.445	4	.010H	.010H
Pontiac 25	120	7.10/15	6-3 9/16 x 4	239.2	IL	6.80	100@3400	.418	4	.011H	.013H
" 27	120	7.10/15	8-3 3/8 x 3 3/4	268.4	IL	6.80	118@3600	.439	5	.011H	.013H
Studebaker 12G	115	6.40/15	6-3 x 4	169.6	IL	7.00	85@4000	.501	4	.016C	.016C
" 3H	115	7.10/15	8-3 3/8 x 3 3/4	232.6	VO	7.00	120@4000	.515	5	.015C	.015C
Willys 685	108	5.90/15	6-3 1/8 x 3 1/2	161.0	IF	7.60	90@4400	.559	4	.011	.027

ABBREVIATIONS:

A - American Bosch
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
B - Before Top Center
C - Carter Carburetor
CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug
CS - Coil Spring
CaS - Cantilever Spring
D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco-Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs
E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
F - Ford
FA - Ford or American Bosch
FE - Full Elliptic Leaf Spring
FH - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley Carburetor
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement
Hy - Hydramatic Transmission
hy - Hydraulic Tappets
IC - Independent Suspension W/Coil Spring

and Tuneup Specifications

Intake Tappet Clearance For Valve Timing	Intake Valve Opens — Degrees	Make of Carburetor	Make of Ignition System	Breaker Point Gap	Breaker Points Open—Degrees	Spark Plug Make	Spark Plug Model	Spark Plug Gap	Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Caster—Degrees	Camber—Degrees	Toe-In	King Pin Inclination	Capacity Cooling System	Capacity Crankcase	Lowest Price Four-Door Sedan	Weight Lowest Price Four-Door Sedan
.020	9B	C	DR	.022	5B	AL	A7	.030	30	Ex	IC	Se	0	5/8	7/32	4 3/8	10.8	4		2395
.004	13B	CS	DR	.018	4B	AC	46X	.026	TQ,O	TT	IC	CS	7/8	1/8	3/32	4 1/4	15	5 1/2	$2192.	3665
.004	14B	CS	DR	.018	4B	AC	46X	.026	TQ,O	TT	IC	CS	7/8	1/8	3/32	4 1/4	15	7	2545.	3825
.004	14B	CS	DR	.018	6B	AC	46X	.026	TQ	TT	IC	CS	7/8	1/8	3/32	4 1/4	19 1/2	7	3179.	4285
	14B	CR	DR	.013	5B	AC	48	.035	Hy	Ex	IC	Se	0	0	1/16	5 5/6	20	5	3638.	4040
	1B	R	DR	.018	5B	AC	46-5	.035	3	TT	IC	Se	1/2	1/2	1/16	4 3/4	16	5	1659.	3115
	16B	R	DR	.018	5B	AC	46-5	.035	TQ	TT	IC	Se	1/2	1/2	1/16	4 3/4	16	5	1749.	3115
.014	12B	CB	AL	.019	2B	AL	AR-8	.035	Fm	Ex	IC	Se	-2	0	1/32	5 3/8	15	5	2480.	3640
	15B	C	AL	.017	4B	AL	4S-140	.035	Fm	Ex	IC	Se	-2	0	1/32	5 3/8	26	5	3192.	4205
.005	5B	C	AL	.020	12B	AL	AN-7E	.025	3	TT	IS	CaS	7 1/2	2	1/16	6 1/2	5	2	1033.	1363
.014	12B	CB	AL	.020	2B	AL	AR-8	.035	HT	Ex	IC	Se	-2	0	1/32	5 3/8	16	5	2316.	3540
	12B	C	AL	.017	4B	AL	4S-140	.035	HT	Ex	IC	Se	-2	0	1/32	5 3/8	23	5	2721.	3760
.014	8B	S	AL	.020	2B	AL	AR-8	.035	HT	Ex	IC	Se	0	0	1/32	5 3/8	15	5	2149.	3140
		Ho	F	.025	TC	CH	H-10	.035	TQ,O	Ex	IC	Se	-1/4	1/2	3/32	5	15	4	1681.	3173
.014	5B	Ho	F		2B	CH	H-10	.030	TQ,O	Ex	IC	Se	-1/4	1/2	1/16	5 1/2	22	4	1757.	3207
.020	9B	C	AL	.020	TC	AL	AN-7	.030	3	Ex		Se	1/2	1/2	3/16	4 3/8	9	4	1349.	2293
.020	5B	C	AL	.020	TC	AL	AN-7	.030	3	Ex	IC	Se	1/2	1/2	3/16	4 3/8	9	5	1494.	2341
.008	27B	C	AL	.020	TC	CH	H-8	.032	AO	Ex	IC	Se	1	1	1/32	3 1/2	19 1/2	7	2297.	3335
.008	27B	C	AL	.020	TC	CH	H-8	.032	AO	Ex	IC	Se	1	1	1/32	3 1/2	19 1/2	7	2448.	3485
.008	27B	C	AL	.020	TC	CH	Hil	.032	AO	Ex	IC	Se	1	1	1/32	3 1/2	19 1/2	7	2655.	3600
.008	10 2/3B	C	AL	.017	TC	CH	H-8	.032	AO	Ex	IC	Se	1	1	1/32	3 1/2	19 1/2	7	2749.	3630
.014	10B	CS		.020	4B	AL	A-5	.032	AO	Ex	IC	Se	0	3/8	3/32	5 1/8	13 1/2	5 1/2	2317.	3126
.006	5B	Ho	F	.015	4B	CH	H-10	.031	AO	Ex	IC	Se	-3/4	1/2	1/8	5	22 1/2	6 1/2	3454.	4125
.006	5B	Ho	F	.015	4B	CH	H-10	.031	AO	Ex	IC	Se	-3/4	1/2	1/8	5	22 1/2	6 1/2	3597.	4140
.015	10B	Ho	F	.015	2B	CH	H-10	.031	AO	Ex	IC	Se	-3/4	1/2	1/8	5	22	6	2232.	3390
.019	6B	C	DR	.022	TC	AL	A-7A	.030	AO	Ex	IC	Se	1	1/2	3/16	8	12	5	1990.	1731
.019	6B	C	DR	.022	TC	AL	A-7A	.030	AO	TT	IC	CS	1/4	0	5/32	6 1/2	15	5	2160.	1792
.023	12°30'B	C	DR	.022	TC	AL	A-7A	.030	AO	TT	IC	CS	1/4	0	5/32	6 1/2	18	6	2534.	2173
.003	13°30'	R	DR	.016	2 1/2B	AC	46-5	.030	AO	Ex	IC	Se	-1/2	1/2	3/32		22 1/2	5	2311.	3608
.003	13°30'	CR	DR	.016	2 1/2B	AC	46-5	.030	AO	Ex	IC	Se	-1/2	1/2	3/32		22 1/2	5	2445.	3649
.003	13°30'	CR	DR	.016	2 1/2B	AC	46-5	.030	AO	Ex	IC	Se	-1/2	1/2	7/32		22 1/2	5	2767.	3765
.012	15B	C	AL/DR	.017	6B	CH	J-8	.026	AO	Ex	IP	Se	1	3/8	1/32	5°50'	20	7	2528.	3680
	15B	C	AL/DR	.017	6B	CH	J-8	.026	AO	Ex	IP	Se	1	3/8	1/32	5°50'	20	7	3293.	3805
	15B	C	AL/DR	.017	6B	CH	J-8	.026	AO	Ex	IP	Se	1	3/8	1/32	5°50'	20	7	3094.	3880
	15B	C	AL	.017	6B	CH	J-8	.026	3	Ex	IP	Se	1	3/8	1/32	5°50'	20	7	3767.	4115
.012	12B	CB	AL	.020	2B	AL	AR-8	.035	3	Ex	IC	Se	0	0	1/32	5 3/4	14	5	2273.	2959
.012	12B	CB	AL	.020	2B	AL	AR-8	.035	3	Ex	IC	Se	0	0	1/32	5 3/4	14	5	1811.	3068
.015C	5B	R	DR	.022	6B	AC	44-5	.026	AO	Ex	IC	Se	-3/4	0	1/32	5	20	5	2001.	3278
.015C	5B	C	DR	.016	6B	AC	44-5	.026	AO	Ex	IC	Se	-3/4	0	1/32	5	21	5	2075.	3378
.020	15B	C	AL	.020	2B	CH	J-7	.025	AO	Ex	IC	Se	-1 3/4	1/2	3/32	6	11 1/2	5	1752.	
.020	11B	S	DR	.016	8B	CH	H-8	.035	AO	Ex	IC	Se	-1 3/4	1/2	3/32	6	18 3/4	6	2107.	
.020	9B	C	AL	.020	TC	CH		.030	3	Ex	IC	Se	0	1 1/2	1/2	8 1/4	12	5	1989.	2570

IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves
J - Johnson Carburetor
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders
R - Rochester Carburetor
S - Stromberg Carburetor
SV - Sliding Valves

Se - Semi-elliptic Springs
Sch - Schebler Carburetor
Ste - Stewart Carburetors
TA - Torque Arms
TC - Top Center
TH - T-head Engine
TQ - Torque Converter
TT - Torque Tube
Til - Tillotson Carburetor
Tr - Transverse Springs

VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical and

1953

MAKE AND MODEL	Wheelbase	Tire Size	Number of Cylinders, Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower @ R.P.M	H. P. Per Cubic Inch	No. of Main Bearings	Operating Tappet Clearance	
										Intake	Exhaust
Allstate "4"	100	5.90/15	4-3 1/8 x 4 3/8	134.2	IL	7.00	68@4000	.507	3	.016C	.016C
" "6"	100	5.90/15	6-3 1/8 x 3 1/2	161.0	IL	7.00	80@3800	.497	4	.016C	.016C
Buick 8-40	121 1/2	7.60/15	8-3 3/16 x 4 1/8	263.3	IO	7.00	125@3800	.475	5	.015	.015
" V8-50	121 1/2	7.60/15	8-4 x 3 13/64	322.0	VO	8.00	164@4000	.509	5	hy	hy
" V8-70	121 1/2	8.00/15	8-4 x 3 13/64	322.0	VO	8.50	188@4000	.584	5	hy	hy
Cadillac 60	130	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	8.25	210@4150	.634	5	hy	hy
" 62	126	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	8.25	210@4150	.634	5	hy	hy
" 75	146 3/4	8.20/15	8-3 13/16 x 3 5/8	331.0	VO	8.25	210@4150	.634	5	hy	hy
Chevrolet 1500	115	6.70/15	6-3 9/16 x 3 15/16	235.5	IO	7.10	108@3600	.459	4	.006	.013
" 2100	115	6.70/15	6-3 9/16 x 3 15/16	235.5	IO	7.50	115@3600	.488	4	hy	hy
Chrysler C-60	125 1/2	7.60/15	6-3 7/16 x 4 3/4	264.5	IL	7.00	119@3600	.450	4	.008	.010
" C-56	133 1/2	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	7.50	180@4000	.544	5	hy	hy
De Soto S-18	125 1/2	7.60/15	6-3 7/16 x 4 1/2	250.6	IL	7.00	116@3600	.463	4	.008	.010
" S-16	125 1/2	7.60/15	8-3 5/8 x 3 13/32	276.1	VO	7.10	160@4400	.580	5	hy	hy
Dodge D-46	119	6.70/15	6-3 1/4 x 4 5/8	230.2	IL	7.00	103@3600	.447	4	.010	.010
" D-44	119	7.10/15	8-3 7/16 x 3 1/4	241.3	VO	7.10	140@4400	.580	5	hy	hy
Ford 6	115	6.70/15	6-3.56 x 3.6	215.3	IO	7.00	101@3500	.469	4	.015	.015
" 8	115	6.70/15	8-3.19 x 3 3/4	239.4	VL	7.20	110@3800	.459	3	.014C	.018C
Henry J 533	100	5.90/15	4-3 1/8 x 4 3/8	134.2	IL	7.00	68@4000	.507	3	.016C	.016C
" 534	100	5.90/15	6-3 1/8 x 3 1/2	161.0	IL	7.00	80@3800	.495	4	.016C	.016C
Hudson 4-C	119 7/8	7.10/15	6-3 9/16 x 3 7/8	232.0	IL	7.20	112@4000	.483	4	.008	.010
" 5-C	119 7/8	7.10/15	6-3 9/16 x 4 3/8	262.0	IL	7.20	127@4000	.485	4	.008	.010
" 7-C	123 7/8	7.10/15	6-3 13/16 x 4 1/2	308.0	IL	7.20	145@3800	.471	4	.008	.010
Kaiser 531	118 1/2	6.70/15	6-3 5/16 x 4 3/8	226.2	IL	7.30	118@3650	.522	4	.014C	.014C
Lincoln	123	8.00/15	8-3.8 x 3 1/2	317.5	VO	8.00	205@4200	.646	5	hy	hy
Mercury	118	7.10/15	8-3.19 x 4	255.4	VL	7.20	125@3800	.489	3	.014C	.018C
Nash 5310	100	6.40/15	6-3 1/8 x 4	184.0	IL	7.25	85@3800	.462	4	.015	.015
" 5340	114 1/2	6.70/15	6-3 1/8 x 4 1/4	195.6	IL	7.45	100@3800	.511	4	.015	.015
" 5360	121 1/4	7.10/15	6-3 1/2 x 4 3/8	252.6	IO	7.30	120@3700	.475	7	.012	.016
Oldsmobile DeLuxe 88	120	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	8.00	150@3600	.494	5	hy	hy
" Super 88	120	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	8.00	165@3600	.543	5	hy	hy
" 98	124	7.60/15	8-3 3/4 x 3 7/16	303.7	VO	8.00	165@3600	.543	5	hy	hy
Packard 2601	122	7.60/15	8-3 1/2 x 3 3/4	288.0	IL	7.70	150@4000	.521	5	.007	.010
" 2611	122	7.60/15	8-3 1/2 x 4 1/4	327.0	IL	8.00	160@3600	.489	5	.007	.010
" 2631	122	8.00/15	8-3 1/2 x 4 1/4	327.0	IL	8.00	180@4000	.550	7	hy	hy
Plymouth P-24	114	6.70/15	6-3 1/4 x 4 3/8	217.8	IL	7.10	100@3600	.459	4	.010	.010
Pontiac 25	122	7.10/15	6-3 9/16 x 4	239.2	IL	7.00	115@3800	.481	4	.012	.012
" 27	122	7.10/15	8-3 3/8 x 3 3/4	268.4	IL	6.80	118@3600	.440	5	.012	.012
Studebaker 14-G	116 1/2	6.40/15	6-3 x 4	169.6	IL	7.00	85@4000	.501	4	.016C	.016C
" 4-H	120 1/2	7.10/15	8-3 3/8 x 3 1/4	232.6	VO	7.00	120@4000	.516	5	.022	.022
Willys 685-A	108	5.90/15	6-3 1/8 x 3 1/2	161.0	IF	7.60	90@4200	.559	4	.018	.016
" 675-A	108	5.90/15	6-3 1/8 x 3 1/2	161.0	IF	6.90	75@4000	.466	4	.018	.016

ABBREVIATIONS:

A - American Bosch
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
B - Before Top Center
C - Carter Carburetor
CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug

CS - Coil Spring
CaS - Cantilever Spring
D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco-Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs
E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
F - Ford

FA - Ford or American Bosch
FE - Full Elliptic Leaf Spring
FH - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley Carburetor
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement
Hy - Hydramatic Transmission
hy - Hydraulic Tappets
IC - Independent Suspension W/Coil Spring

Tuneup Specifications

Intake Tappet Clearance For Valve Timing	Intake Valve Opens—Degrees	Make of Carburetor	Make of Ignition System	Breaker Point Gap	Breaker Points Open—Degrees	Spark Plug Make	Spark Plug Model	Spark Plug Gap	Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Caster—Degrees	Camber—Degrees	Toe-In	King Pin Inclination	Capacity Cooling System	Capacity Crankcase	Lowest Price Four-Door Sedan	Weight Lowest Price Four-Door Sedan
.020	9B	C	DR	.022	5B	AL	A7	.030	30	Ex	IC	Se	0	5/8	7/32	4 3/8	10.8	4		2395
.020	5B	C	DR	.022	TC	AL	A7	.030	30	Ex	IC	Se	0	5/8	7/32	4 3/8	9 1/2	5		2395
.004	13B	S-C	DR	.016	4B	AC	46x	.025	3/TQ	TT	IC	CS	1/8	1/8	3/32	4 1/4	12	5 1/2	$2255.	3710
hy	25B	S-C	DR	.016	5B	AC	44-5	.032	3/TQ	TT	IC	CS	1/8	1/8	3/32	4 1/4	16 1/2	6	2695.	3905
hy	25B	S-C	DR	.016	5B	AC	44-5	.032	TQ	TT	IC	CS	1/8	1/8	3/32	4 1/4	18	6	3254.	4100
hy	22B	C-R	DR	.013	2 1/2B	AC	46-5	.035	Hy	Ex	IC	Se	0	0	3/32	5	19 3/4	5	4305.	4415
hy	22B	C-R	DR	.013	2 1/2B	AC	46-5	.035	Hy	Ex	IC	Se	0	0	3/32	5	19 3/4	5	3666.	4225
hy	22B	C-R	DR	.013	2 1/2B	AC	46-5	.035	Hy	Ex	IC	Se	0	0	3/32	5	19 3/4	5	5408.	4830
.008	1A	R	DR	.015	5B	AC	44-5	.036	3	TT	IC	Se	1/2	1/2	1/16	4	15	5	1670.	3215
hy	16B	R	DR	.015	5B	AC	44-5	.036	3/TQ	Ex	IC	Se	1/2	1/2	1/16	4	15	5	1761.	3250
.014	12B	C	AL	.019	TC	AL	AR8	.035	Var O	Ex	IC	Se	1	0	1/32	5 3/4	15	5	2577.	3655
hy	15B	C	AL	.017	4B	AL	AR8	.035	Var O	Ex	IC	Se	1	0	1/32	5 3/4	25	5	3365.	4000
.014	12B	C	AL	.019	2B	AL	AR8	.035	Var O	Ex	IC	Se	1	0	1/32	5 3/4	15	5	2456.	3555
hy	12B	C	AL	.017	4B	AL	4s-140	.035	Var O	Ex	IC	Se	1	0	1/32	5 3/4	22	5	2740.	3705
.014	8B	C	AL	.020	2B	AL	AR8	.035	Var O	Ex	IC	Se	1	0	1/32	5 3/4	14	5	2071.	3196
hy	17B	S	AL	.017	4B	AL	4s-140	.035	Var O	Ex	IC	Se	1	0	1/32	5 3/4	19	5	2348.	3385
.013	13B	Ho	F-A	.025	TC	CH	H-10	.036	30/TQ	Ex	IC	Se	-1/4	1/2	3/32	5	15	4	1675.	3105
.018	5B	Ho	F-A	.015	2B	CH	H-10	.036	30/TQ	Ex	IC	Se	-1/4	1/2	3/32	5	22	4	1751.	3171
.020	9B	C	DR	.022	5B	AL	A7	.030	30	Ex	IC	Se	0	5/8	7/32	4 3/8	10.8	4	1499.	2395
.020	5B	C	DR	.022	TC	AL	A7	.030	30	Ex	IC	Se	0	5/8	7/32	4 3/8	9 1/2	5	1686.	2445
.008	26 3/4B	C	AL	.020	TC	CH	H-8	.032	3°Hy	Ex	IC	Se	1	1	1/32	3 1/2	18 1/2	7	2311.	3880
.008	26 3/4B	C	AL	.020	TC	CH	H-8	.032	3°Hy	Ex	IC	Se	1	1	1/32	3 1/2	18 1/2	7	2466.	3480
.008	26 3/4B	C	AL	.020	TC	CH	H-11	.032	3°Hy	Ex	IC	Se	1	1	1/32	3 1/2	18 1/2	7	2769.	3570
.018	10B	C	DR	.022	4B	AL	A7	.030	30/Hy	Ex	IC	Se	0	3/8	3/32	5 1/8	12 1/2	5	2650.	3265
hy	18B	Ho	F	.015	3B	CH	H-10	.036	30/Hy	Ex	IC	Se	-3/4	3/8	1/8	7 1/6	22 1/2	5	3226.	4135
.018	5B	Ho	F-A	.015	2B	CH	H-10	.031	30/TQ	Ex	IC	Se	-3/4	3/8	1/8	5	21 1/2	4	2057.	3450
.015	10B	C	DR	.022	4B	AL	A7A	.030	30/Hy	Ex	IC	Se	1	1/2	3/16	8	12	4	2000.	3045
.015	10B	C	DR	.022	4B	AL	A7A	.030	30/Hy	TT	IC	CS	1/4	0	5/32	6 1/2	15	4	2433.	3095
.023	12 1/2B	C	DR	.022	TC	AL	A7A	.030	30/Hy	TT	IC	CS	1/4	0	5/32	6 1/2	18	6	2557.	3430
.003	13 1/2B	C	DR	.016	2 1/2B	AC	46-5	.030	3/Hy	Ex	IC	Se	-3/8	1/4	5/32	5	21 1/2	5	2327.	3642
.003	13 1/2B	R	DR	.015	2 1/2B	AC	46-5	.030	3/Hy	Ex	IC	Se	-3/8	1/4	5/32	5	21 1/2	5	2462.	3673
hy	13 1/2B	C	DR	.015	2 1/2B	AC	46-5	.030	3/Hy	Ex	IC	Se	-3/8	1/4	5/32	5	21 1/2	5	2786.	3779
.013	15B	C	DR	.015	6B	CH	J-8	.026	3/TQ	Ex	IC	Se	1/2	3/8	1/32	5 1/2	20	7	2588.	3715
.013	15B	C	DR	.015	6B	CH	J-8	.026	3/TQ	Ex	IC	Se	1/2	3/8	1/32	5 1/2	20	7	2735.	3745
hy	15B	C	AL	.015	6B	CH	J-8	.026	3/TQ	Ex	IC	Se	1/2	3/8	1/32	5 1/2	20	7	3234.	3960
.014	12B	C	AL	.020	2B	AL	AR8	.035	30/TQ	Ex	IC	Se	0	0	1/32	5 3/4	13	5	1822.	2970
.015	12 1/2B	C	DR	.022	TC	AC	44-5	.026	3/Hy	Ex	IC	Se	0	1/2	1/32	5 1/4	18.3	5	2015.	3381
.015	12 1/2B	C	DR	.016	6B	AC	44-5	.026	3/Hy	Ex	IC	Se	0	1/2	1/32	5 1/4	19 1/2	5	2090.	3456
.020	15B	C	AL	.020	2B	CH	J-7	.025	30/TQ	Ex	IC	Se	-1/2	1/2	3/32	6	10	5	1767.	2710
.030	11B	S	DR	.016	4B	CH	H-10	.035	30/TQ	Ex	IC	Se	-1/2	1/2	3/32	6	17 1/4	6	2121.	3075
.027	9B	C	AL	.020	TC	CH	J-8	.030	30	Ex	IC	Se	0	1 1/2	1/8	8 1/4	11	5	1732.	2507
.020	5B	C	AL	.020	TC	CH	J-8	.030	30	Ex	IC	Se	0	1 1/2	1/8	8 1/4	11	5	2038.	2588

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VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
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3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

1954

MAKE AND MODEL	Wheelbase	Tire Size	Number of Cylinders, Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower @ R. P. M.	H. P. Per Cubic Inch	No. of Main Bearings	Operating Tappet Clearance		Intake Tappet Clearance For Valve Timing
										Intake	Exhaust	
Buick 40	122	15/7.60	V8-3 5/8 x 3.20	264.0	VO	7.2	143@4200	.541	5	hy	hy	.004
" 60	122	15/7.60	V8-4 x 3.20	322.0	VO	8.0	195@4100	.606	5	hy	hy	.004
" 50	127	15/7.60	V8-4 x 3.20	322.0	VO	8.0	195@4100	.606	5	hy	hy	.004
" 70	127	15/8.00	V8-4 x 3.20	322.0	VO	8.5	200@4100	.621	5	hy	hy	.004
Cadillac 6219, 6237, 6267	129	15/8.00	V8-3.8125 x 3.625	331.0	VO	8.25	230@4400	.695	5	hy	hy	
" 6019	133	15/8.00	V8-3.8125 x 3.625	331.0	VO	8.25	230@4400	.695	5	hy	hy	
" 75	149.8	15/8.20	V8-3.8125 x 3.625	331.0	VO	8.25	230@4400	.695	5	hy	hy	
Chevrolet 150	115	15/6.40	6-3 9/16 x 3 15/16	235.5	IO	7.5	115@3700	.490	4	.010H	.020H	.000
" 210	115	15/6.40	6-3 9/16 x 3 15/16	235.5	IO	7.5	125@4000	.522	4	hy	hy	hy
" Bel Air	115	15/6.40	6-3 9/16 x 3 15/16	235.5	IO	7.5	125@4000	.522	4	hy	hy	hy
Chrysler C-62	125 1/2	15/7.60	6-3 7/16 x 4 3/4	264.5	IL	7.0	119@3600	.450	4	.008H	.010H	.014
" C-63	125 1/2	15/8.00	V8-3 13/16 x 3 5/8	331.1	VO	7.5	195@4400	.590	5	hy	hy	hy
" C-64	133 1/2	15/8.20	V8-3 13/16 x 3 5/8	331.1	VO	7.5	235@4400	.709	5	hy	hy	hy
" C-66	145 1/2	15/8.90	V8-3 13/16 x 3 5/8	331.1	VO	7.5	235@4400	.709	5	hy	hy	hy
De Soto S-19	125 1/2	15/7.60	V8-3 5/8 x 3 11/16	276.1	VO	7.5	170@4400	.615	5	hy	hy	hy
" S-20	125 1/2	15/7.60	6-3 7/16 x 4 1/2	250.6	IL	7.0	116@3600	.464	4	.008H	.010H	.014
Dodge D-50	119	15/6.70	V8-3 7/16 x 3 1/4	241.3	VO	7.5	150@4400	.622	5	hy	hy	hy
" D-51	119	15/6.70	6-3 1/4 x 4 5/8	230.2	IL	7.25	110@3600	.478	4	.010H	.010H	.014
" D-52	119	15/6.70	6-3 1/4 x 4 5/8	230.2	IL	7.25	110@3600	.478	4	.010H	.010H	.014
" D-53	119	15/6.70	V8-3 7/16 x 3 1/4	241.3	VO	7.5	150@4400	.622	5	hy	hy	hy
Ford 6		15/6.70	6-3.62 x 3.60	223.0	IO	7.2	115@3900	.515	4	.019	.019	.019
" 8		15/6.70	V8-3.50 x 3.10	239.0	VO	7.2	130@4200	.545	5	hy	hy	hy
Henry J 543	100	15/5.90	4-3.125 x 4.375	134.2	IL	7.0	68@4000	.505	3	.016C	.016C	.020
" 544	100	15/5.90	6-3.125 x 3.5	161.0	IL	7.0	80@3800	.496	4	.016C	.016C	.020
Hudson Jet 1D, 2D, 3D	105	15/5.90	6-3 x 4 3/4	202.0	IL	7.5	104@4000	.515	4	.010H	.012H	.010
Hudson Wasp 4-D	119 7/8	15/7.10	6-3 9/16 x 3 7/8	232.0	IL	7.5	126@4400	.543	4	.008H	.010H	.008
Hudson Super Wasp 5-D	119 7/8	15/7.10	6-3 9/16 x 4 3/8	262.0	IL	7.5	140@4000	.535	4	.008H	.010H	.008
Hudson Hornet 7-D	123 7/8	15/7.10	6-3 13/16 x 4 1/2	308.0	IL	7.5	160@3800	.520	4	.008H	.010H	.008
Kaiser K-545	118 1/2	15/6.70	6-3 5/16 x 4 3/8	226.2	IL	7.3	118@3650	.520	4	.014C	.014C	.020
" K-542	118 1/2	15/6.70	6-3.313 x 4 3/8	226.2	IL	7.3	140@3800		4	.014C	.014C	.018
Lincoln	123	15/8.00	V8-3.80 x 3.50	317.0	VO	8.0	205@4200	.648	5	hy	hy	hy
Mercury	118	15/7.10	V8-3.62 x 3.10	256.0	VO	7.5	161@4400	.630	5	.019H	.019H	.0165
Nash 5410	100	15/6.40	6-3 1/8 x 4	184.0	IL	7.25	85@3800	.461	4	.015H	.015H	.015
" 5410	108	15/6.40	6-3 1/8 x 4 1/4	195.6	IL	7.3	90@3800	.460	4	.015H	.015H	.015
" 5440	114 1/4	15/6.70	6-3 1/8 x 4 1/4	195.6	IL	8.5	110@4000	.564	4	.015H	.015H	.015
" 5460	121 1/4	15/7.10	6-3 1/2 x 4 3/8	252.5	IO	7.6	130@3700	.515	7	.012H	.016H	.023
Nash LeMano Jet Fire	121 1/4	15/7.10	6-3 1/2 x 4 3/8	252.5	IO	8.0	140@3700	.555	7	.012H	.016H	.023
Oldsmobile 88	122	15/6.50	V8-3 7/8 x 3 7/16	324.3	VO	8.25	170@4000	.525	5	hy	hy	hy
" Super-88	122	15/6.50	V8-3 7/8 x 3 7/16	324.3	VO	8.25	185@4000	.571	5	hy	hy	hy
" 98	126	15/6.50	V8-3 7/8 x 3 7/16	324.3	VO	8.25	185@4000	.571	5	hy	hy	hy
Packard 5400	122	15/7.60	8-3 1/2 x 3 3/4	288.0	IL	7.7	150@4000	.521	5	.007H	.010H	.015
" 5401, 5411	122	15/7.60	8-3 1/2 x 4 1/4	327.0	IL	8.0	165@3600	.505	5	.007H	.010H	.015
" 5402	127	15/8.00	8-3 1/2 x 4 1/4	327.0	IL	8.0	185@4000	.566	5	hy	hy	hy
" 5431	122	15/8.00	8-3 9/16 x 4 1/2	359.0	IL	8.7	212@4000	.590	7	hy	hy	hy
" 5406	127	15/8.00	8-3 9/16 x 4 1/2	359.0	IL	8.7	212@4000	.590	7	hy	hy	hy
" 5426	149	15/8.20	8-3 9/16 x 4 1/2	359.0	IL	8.7	212@4000	.590	7	hy	hy	hy
Plymouth P-25	114	15/6.70	6-3 1/4 x 4 3/8	217.8	IL	7.1	100@3600	.460	4	.010H	.010H	.014
Pontiac 54-25	122	15/7.10	6-3 9/16 x 4	239.2	IL	7.0	115@3800	.481	4	.012H	.012H	.015
" 54-27	122	15/7.10	8-3 3/8 x 3 3/4	268.4	IL	6.8	122@3800	.455	5	.012H	.012H	.015
" 54-28	124	15/7.10	8-3 3/8 x 3 3/4	268.4	IL	7.7	127@3800	.475	5	.012H	.012H	.015
Studebaker Champion 15G	116 1/2	15/6.70	6-3 x 4	169.6	IL	7.5	85@4000	.504	4	.016C	.016C	.020
Studebaker Commander 5-H	120 1/2	15/7.10	V8-3 3/8 x 3 1/4	232.6	VO	7.5	120@4000	.518	5	.024C	.024C	.030
Studebaker Land Cru. 5-HY	120 1/2	15/7.10	V8-3 3/8 x 3 1/4	232.6	VO	7.5	120@4000	.518	5	.024C	.024C	.030

ABBREVIATIONS:

A - American Bosch
A - After Top Center
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
B - Before Top Center
b - When equipped with Dynaflow Transmission - 20 Qt.
C - Carter Carburetor

CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug
CS - Coil Spring
CaS - Cantilever Spring
D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco-Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs

E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
F - Ford
FA - Ford or American Bosch
FE - Full Elliptic Leaf Spring
FH - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley Carburetor
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement

Tuneup Specifications

Intake Valve Opens Degrees	Make of Carburetor	Make of Ignition System	Breaker Point Gap	Breaker Points Open — Degrees	Spark Plugs		Spark Plug Gap	Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Wheel Alignment				Capacity Cooling System - Qts.	Capacity Crankcase	Lowest Price Four - Door Sedan	Weight Lowest Price Four - Door Sedan
					Make	Model						Caster Degrees	Camber Degrees	Toe-In	King Pin Inclination				
25B	S,C	DR	.015	5B	AC	44-5	.032	3/TQ	TT	IC	CS	- 1/8	+ 1/8	1/32	0	18b	6	2265	3714
25B	S,C	DR	.015	5B	AC	44-5	.032	3/TQ	TT	IC	CS	- 1/8	+ 1/8	1/32	0	18b	6	2520	3786
25B	S,C	DR	.015	5B	AC	44-5	.032	3/TQ	TT	IC	CS	- 1/8	+ 1/8	1/32	0	18b	6	2711	4105
25B	S,C	DR	.015	5B	AC	44-5	.032	TQ	TT	IC	CS	- 1/8	+ 1/8	1/32	0	20	6	3269	4205
22B	C,R	DR	.016	2 1/2B	AC	46-5	.035	Hy	Ex	IC	Se	- 1/2	0	3/16	5 5/6	22	5	3384	4225
22B	C,R	DR	.016	2 1/2B	AC	46-5	.035	Hy	Ex	IC	Se	- 1/2	0	3/16	5 5/6	22	5	3969	4415
22B	C,R	DR	.016	2 1/2B	AC	46-5	.035	Hy	Ex	IC	Se	- 1/2	0	3/16	5 5/6	24 1/2	5	4988	4830
1A	R	DR	.015	2A	AC	44-5	.035	3	TT	IC	Se	+ 1/2	+ 1/2	1/8	4	17	5	1530	3210
1A	R	DR	.015	2A	AC	44-5	.035	TQ	TT	IC	Se	+ 1/2	+ 1/2	1/8	4	17	5	1615	3255
1A	R	DR	.015	2A	AC	44-5	.035	TQ	TT	IC	Se	+ 1/2	+ 1/2	1/8	4	17	5	1720	3380
12B	C	AL	.019	TC	AL	4S-140	.035	3	Ex	IC	Se	-2	0	1/32	5 3/4	16	5	2350	3685
15B	C	AL	.017	4B	AL	4GS-150	.035	TQ	Ex	IC	Se	-2	0	1/32	5 3/4	26	5	2965	3955
15B	C	AL	.017	4B	AL	4GS-150	.035	TQ	Ex	IC	Se	-2	0	1/32	5 3/4	26	5	3155	4060
15B	C	AL	.017	4B	AL	4GS-150	.035	TQ	Ex	IC	Se	-2	0	1/32	5 3/4	26	5	4205	4355
12B	C	AL	.017	4B	AL	4S-140	.035	TQ	Ex	IC	Se	-2	0	1/32	5 3/4	23-	5	2453	3750
12B	C	AL	.019	2B	AL	4S-140	.035	3	Ex	IC	Se	-2	0	1/32	5 3/4	16	5	2186	3590
17B	S	AL	.017	4B	AL	4S-140	.035	TQ	Ex	IC	Se	0	0	0	5 3/4	20	5	1995	3390
12B	C	AL	.020	2B	AL	4S-140	.035	3	Ex	IC	Se	0	0	0	5/3/4	15	5	1855	3195
12B	C	AL	.020	2B	AL	4S-140	.035	3	Ex	IC	Se	0	0	0	5 3/4	15	5	1958	3235
17B	S	AL	.017	4B	AL	4S-140	.035	TQ	Ex	IC	Se	0	0	0	5 3/4	20	5	2178	3425
13B	HO	HO	.025	3B	CH	H-10	.035	3	Ex	IC	Se	+ 1/2	+ 3/4	3/32	7	15	4	1542	3142
8B	HO	HO	.015	6B	CH	H-10	.035	TQ	Ex	IC	Se	+ 1/2	+ 3/4	3/32	7	20	5	1613	3263
9B	C	DR	.022	5B	AL	A-7	.030	3,0	Ex	IC	Se	0	+ 1/2	1/4	4 1/2	11.8	4	1399	2395
5B	C	DR	.022	5B	AL	A-7	.030	3,0	Ex	IC	Se	0	+ 1/2	1/4	4 1/2	10.5	5	1561	2445
26.8B	C	AL	.020	TC	CH	H-10	.032	3	Ex	IC	Se	+1	+ 3/4	1/32	4	16	5	1685	2675
33.7B	C	AL	.020	TC	CH	H-10	.032	30/TQ	Ex	IC	Se	+1	+1	1/32	3 1/2	19 1/2	7	2056	3440
33.7B	C	AL	.020	TC	CH	H-10	.032	30/TQ	Ex	IC	Se	+1	+1	1/32	3 1/2	19 1/2	7	2252	3525
33.7B	C	AL	.020	TC	CH	H-10	.032	30/TQ	Ex	IC	Se	+1	+1	1/32	3 1/2	19 1/2	7	2530	3620
10B	C	DR	.022	4B	AL	A-7	.030	3,0,Hy	Ex	IC	Se	0	+ 1/2	1/8	5	13 1/2	5	2444	3275
10B	C	DR	.016	4B	AL	A-7	.030	3,0,Hy	Ex	IC	Se	0	+ 1/2	1/8	5	13 1/2	5		3375
18B	HO	HO	.015	3B	CH	H-10	.035	Hy	Ex	IC	Se	- 3/4	+ 3/8	1/8	7 1/6	24.5	5	3226	4190
15B	HO	HO	.015	3B	CH	H-10	.031	Hy	Ex	IC	Se	- 3/4	+ 3/8	1/8	7 3/4	20.0	5	2057	3480
10B	C	DR	.022	TC	AL	4-7A	.030	3,0/Hy	Ex	IC	Se	+1	+ 1/2	1/4	8	12	4	1832	2550
10B	C	DR	.022	4A	AL	4-7A	.030	3,0,Hy	Ex	IC	Se	+1	+ 1/2	1/4	8	12	4	2001	2650
10B	C	DR	.022	4A	AL	AL-5B	.030	3,0,Hy	Ex	IC	Se	+ 1/4	0	1/8	6 1/2	15	4	2000	3045
12 1/2B	C	DR	.022	TC	AL	A-7A	.030	3,0,Hy	Ex	IC	Se	+ 1/4	0	1/8	6 1/2	18	6	2215	3430
12 1/2B	C	DR	.022	TC	AL	AL-5B	.030	3,0,H	Ex	IC	Se	+ 1/4	0	1/8	6 1/2	18	6		
13 1/2B	C	DR	.016	5B	AC	46-5	.030	3,Hy	Ex	IC	Se	- 3/8	+ 1/2	3/32	5 5/6	21 1/2	5	2126	3642
13 1/2B	R	DR	.016	5B	AC	46-5	.030	3,Hy	Ex	IC	Se	- 3/8	+ 1/2	3/32	5 5/6	21 1/2	5	2252	3673
13 1/2B	R	DR	.016	5B	AC	46-5	.030	3,Hy	Ex	IC	Se	- 3/8	+ 1/2	3/32	5 5/6	21 1/2	5	2552	3779
15B	C	AL	.015	6B	CH	J-8	.025	3a	Ex	IC	Se	-1	+ 1/4	1/32	5 5/6	20 1/2	7	2695	3790
10B	C	ALa	.015	6B	CH	J-8	.025	3a	Ex	IC	Se	-1	+ 1/4	1/32	5 5/6	20 1/2	7	2815	3795
10B	C	DR	.015	6B	CH	J-8	.025	3a	Ex	IC	Se	-1	+ 1/4	1/32	5 5/6	21	7	3344	4090
22B	C	DR	.015	TC	CH	J-8	.025	3a	Ex	IC	Se	-1	+ 1/4	1/32	5 5/6	21	7	6100	4040
22B	C	DR	.015	TC	CH	J-8	.025	TQ	Ex	IC	Se	-1	+ 1/4	1/32	5 5/6	21	7	3890	4190
22B	C	DR	.015	TC	CH	J-8	.025	TQ	Ex	IC	Se	-1	+ 1/4	1/32	5 5/6	21	7	6900	4785
12B	C	AL	.020	2B	AL	4S-140	.035	30	Ex	IC	Se	0	0	0	5 3/4	14	5	1617	3004
12 1/2B	C	DR	.016	3B	AC	44-5	.025	3	Ex	IC	Se	0	+ 1/2	1/32		20.1	5	1843	3391
5B	C	DR	.016	6B	AC	44-5	.025	3,Hy	Ex	IC	Se	0	+ 1/2	1/32		20.6	5	1913	3451
5B	C	DR	.016	3B	AC	44-5	.025	3,Hy	Ex	IC	Se	0	+ 1/2	1/32		20.6	5	2184	3536
15B	C	AL	.020	2B	CH	J-7	.025	3,0	Ex	IC	Se	-1 1/4	+ 1/2	3/32	6	11 1/2	5	1635	2745
11B	S	DR	.013	4B	CH	H-11	.035	3,0,TQ	Ex	IC	Se	-1 1/4	+ 1/2	3/32	6	18 3/4	6	1845	2780
11B	S	DR	.013	4B	CH	H-11	.035	3,0,TQ	Ex	IC	Se	-1 1/4	+ 1/2	3/32	6	18 3/4	6	2220	3180

Hy - Hydramatic Transmission
hy - Hydraulic Tappets
IC - Independent Suspension W/Coil Spring
IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves
J - Johnson Carburetor
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders

R - Rochester Carburetor
S - Stromberg Carburetor
SV - Sliding Valves
Se - Semi-elliptic Springs
Sch - Schebler Carburetor
Ste - Stewart Carburetors
TA - Torque Arms
TC - Top Center
TH - T-head Engine
TQ - Torque Converter
TT - Torque Tube

Til - Tillotson Carburetor
Tr - Transverse Springs
VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical and

1955

MAKE AND MODEL	Wheelbase	Tire Size	Number of Cylinders, Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower @ R.P.M.	H.P. Per Cu. In.	No. of Main Bearings	Operating Tappet Clearance Intake	Operating Tappet Clearance Exhaust	Intake Tappet Clearance For Valve Timing
Buick Special 40	122.0	7.10/15	8-3 5/8 x 3 13/64	264.0	VO	7.50	188@4200	.712	5	hy	hy	.004
" Super 50	127.0	7.60/15	8-4 x 3 13/64	322.0	VO	8.40	236@4600	.733	5	hy	hy	.004
" Cent. 60	122.0	7.60/15	8-4 x 3 13/64	322.0	VO	8.40	236@4600	.733	5	hy	hy	.004
" Road 70	127.0	8.00/15	8-4 x 3 13/64	322.0	VO	9.00	236@4600	.733	5	hy	hy	.004
Cadillac 60	133.0	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	9.00	250@4600	.755	5	hy	hy	
" 62	129.0	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	9.00	250@4600	.755	5	hy	hy	
" 75	149.8	8.20/15	8-3 13/16 x 3 5/8	331.0	VO	9.00	250@4600	.755	5	hy	hy	
Chevrolet 6	115.0	6.70/15	6-3 9/16 x 3 15/16	235.5	IO	7.50	123@3800	.522	4	.006H	.013H	
" 8	115.0	6.70/15	8-3 3/4 x 3	265.0	VO	8.00	162@4400	.611	5	.006H	.013H	
" Corvette	102.0	6.70/15	6-3 9/16 x 3 15/16	235.5	IO	8.00	150@4200	.637	4	.010H	.020H	
Chrysler C-67	126	7.60/15	8-3 5/8 x 3 5/8	301.0	VO	8.00	188@4400	.625	5	hy	hy	
" C-68	126	8.00/15	8-3 13/16 x 3 5/8	331.0	VO	8.50	250@4600	.755	5	hy	hy	
" C-69	130	8.20/15	8-3 13/16 x 3 5/8	331.0	VO	8.50	250@4600	.755	5	hy	hy	
" C-70	149	8.90/15	8-3 13/16 x 3 5/8	331.0	VO	8.50	250@4600	.755	5	hy	hy	
De Soto S-21	126	7.60/15	8-3 23/32 x 3 11/32	291.0	VO	7.50	185@4400	.636	5	hy	hy	
" S -22	126.0	7.60/15	V8-3 23/32 x 3 11/32	291.0	VO	7.5	185@4400	.635	5	hy	hy	hy
Dodge Cor. 6	120	6.70/15	6-3 1/4 x 4 5/8	230.0	IL	7.40	123@3600	.535	4	.010H	.010H	.014
" D55-1,D55-2	120	7.10/15	8-3 5/8 x 3 1/4	270.0	VO	7.60	175@4400	.648	5	hy	hy	
" Cust. RoyD55-3	120	7.10/15	8-3 5/8 x 3 1/4	270.0	VO	7.60	183@4400	.678	5	hy	hy	
Ford 6	115.5	6.70/15	6-3 5/8 x 3 39/64	223.0	IO	7.50	120@4000	.538	4	.015H	.019H	
" 8	115.5	6.70/15	8-3 5/8 x 3 19/64	272.0	VO	7.60	162@4400	.596	5	.019H	.019H	
" Thunder Bird	102.0	6.70/15	8-3 3/4 x 3 19/64	292.0	VO	8.10	192@4400	.661	5	.018H	.018H	
Hudson Wasp	114.3	6.70/15	6-3 x 4 3/4	202.0	IL	7.50	115@4000	.569	4	.010H	.012H	.010
" Hornet 6	121.3	7.10/15	6-3 13/16 x 4 1/2	308.0	IL	7.50	160@3800	.519	4	.010H	.012H	.010
" Hornet 8	121.3	7.10/15	8-3 13/16 x 3 1/2	320.0	VO	7.80	208@4200	.650	5	hy	hy	
Lincoln	123.0	8.00/15	8-3 15/16 x 3 1/2	341.0	VO	8.50	225@4400	.660	5	hy	hy	
Mercury Cust., Monterey	119.0	7.10/15	8-3 3/4 x 3 19/64	292.0	VO	7.60	188@4400	.644	5	.019H	.019H	
" Montcl.	119.0	7.10/15	8-3 3/4 x 3 19/64	292.0	VO	8.50	198@4400	.678	5	.019H	.019H	
Nash 5540	114.3	6.70/15	6-3 1/8 x 4 1/4	195.6	IL	7.45	100@3800	.511	4	.015H	.015H	.015
" 5560	121.3	7.10/15	6-3 1/2 x 4 3/8	252.6	IO	7.60	130@3700	.515	9	.012H	.016H	.023
" 5580	121.3	7.10/15	8-3 13/16 x 3 1/2	320.0	VO	7.80	208@4200	.650	5	hy	hy	
Nash-Hudson Met.	85.0	5.20/13	4-2 37/64 x 3 1/2	73.2	IL	7.20	42@4500	.574	3	.015C	.015C	.015
" Rambler	100.0	6.40/15	6-3 1/8 x 4 1/4	195.6	IL	7.30	90@3800	.460	4	.015H	.015H	.015
" Rambler	108.0	6.40/15	6-3 1/8 x 4 1/4	195.6	IL	7.30	90@3800	.460	4	.015H	.015H	.015
Oldsmobile 88	122.0	7.10/15	8-3 7/8 x 3 7/16	324.3	VO	8.50	185@4000	.570	5	hy	hy	
" 98	126.0	7.60/15	8-3 7/8 x 3 7/16	324.3	VO	8.50	202@4000	.623	5	hy	hy	
Packard 5540	122.0	7.60/15	8-3 13/16 x 3 1/2	320.0	VO	8.50	225@4600	.703	5	hy	hy	
" 5560	122.0	7.60/15	8-4 x 3 1/2	352.0	VO	8.50	245@4600	.696	5	hy	hy	
" 5580	127.0	8.00/15	8-4 x 3 1/2	352.0	VO	8.50	260@4600	.739	5	hy	hy	
Plymouth P-26	115.0	6.70/15	6-3 1/4 x 4 5/8	230.0	IL	7.40	117@3600	.509	4	.010H	.010H	.014
" P-27	115.0	6.70/15	8-3 7/16 x 3 1/4	241.0	VO	7.60	157@4400	.651	5	hy	hy	
Pontiac Chief 55-27	122.0	7.10/15	8-3 3/4 x 3 1/4	287.2	VO	8.00	180@4600	.627	5	hy	hy	
" Star Ch. 55-28	124.0	7.10/15	8-3 3/4 x 3 1/4	287.2	VO	8.00	180@4600	.627	5	hy	hy	
Studebaker Champ. G6	116.5	6.40/15	6-3 x 4 3/8	185.6	IL	7.50	101@4000	.544	4	.016C	.016C	.020
" Comm. G8	116.5	7.10/15	8-3 9/16 x 3 1/4	259.2	VO	8.00	162@4500	.625	5	.024H	.024H	.030
" Pres. 6H	120.5	7.10/15	8-3 9/16 x 3 1/4	259.2	VO	8.00	175@4500	.675	5	.024H	.024H	.030
Willys 6-226-A	108.0	6.40/15	6-3 5/16 x 4 3/8	226.2	IL	7.30	115@3650	.508	4	.014C	.014C	.018

ABBREVIATIONS:

A - American Bosch
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
B - Before Top Center
C - Carter Carburetor
CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug
CS - Coil Spring
CaS - Cantilever Spring
D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco-Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs
E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
F - Ford
FA - Ford or American Bosch
FE - Full Elliptic Leaf Spring
FH - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley Carburetor
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement
Hy - Hydramatic Transmission
hy - Hydraulic Tappets.
IC - Independent Suspension W/Coil Spring

Tuneup Specifications

Intake Valve Opens–Degrees	Make of Carburetor	Make of Ignition System	Breaker Point Gap	Breaker Point Opens–Degrees	Spark Plug		Spark Plug Gap	Transmission Type	Propeller Shaft	Front Suspension	Wheel Alignment				Capacity Cooling System Quarts	Capacity Crankcase Quarts	Lowest Price Four-Door Sedan	Weight Lowest Price Four-Door Sedan
					Make	Model					Caster–Degrees	Camber–Degrees	Toe-In Inches	King Pin Inclination				
25B	S,C	DR	.015	5B	AC	44-5	.033	3/TQ	TT	IC	-1/8	+ 1/8	1/32	0	20	6	$2090	3725
25B	C,R	DR	.015	5B	AC	44-5	.033	3/TQ	TT	IC	-1/8	+ 1/8	1/32	0	20	6	2621	4140
25B	C,R	DR	.015	5B	AC	44-5	.033	3/TQ	TT	IC	-1/8	+ 1/8	1/32	0	20	6	2315	3825
25B	C,R	DR	.015	5B	AC	44-5	.033	3/TQ	TT	IC	-1/8	+ 1/8	1/32	0	20	6	3047	4300
19B	C,R	DR	.019	2 1/2B	AC	44-5	.035	Hy	Ex	IC	-1/2	0	7/32	5 5/6	20	5	4342	4540
19B	C,R	DR	.019	2 1/2B	AC	44-5	.035	Hy	Ex	IC	-1/2	0	7/32	5 5/6	20	5	3658	4370
19B	C,R	DR	.019	2 1/2B	AC	44-5	.035	Hy	Ex	IC	-1/2	0	7/32	5 5/6	20	5	5695	5015
10.5B	R	DR	.019	TC	AC	44-5	.036	3/TQ	Ex	IC	0	+ 1/2	5/32	4	17	5	1575	3115
12B	R	DR	.019	4B	AC	44-5	.036	3/TQ	Ex	IC	0	+ 1/2	5/32	4	17	4	1667	3075
10.5B	R	DR	.016	2A	AC	44-5	.036	3/TQ	Ex	IC	+1/2	- 1/2	1/16	4	18 1/2	5		2705
15B	C	AL	.017	6B	AL	45-165	.035	Var	Ex	IC	-1	+ 1/2	0	5 1/2	26.0	5	2412	3925
15B	C	AL	.017	6B	AL	4GS-175	.035	Var	Ex	IC	-1	+ 1/2	0	5 1/2	26.0	5	3185	4160
15B	C	AL	.017	6B	AL	4GS-175	.035	Var	Ex	IC	-1	+ 1/2	0	5 1/2	26.0	5	4105	4565
15B	C	AL	.017	6B	AL	4GS-175	.035	Var	Ex	IC	-1	+ 1/2	0	7	26.0	5		
12B	C	AL	.017	4B	AL	4S-165	.035	3/TQ	Ex	IC	-1	+ 1/2	0	5 1/2	24.0	5	2481	3940
4A	CB	AL	.017	4B	AL	4S140	.035	3/TQ	Ex	CS	-2	+ 1/2	1/32	5 1/2	23	5	2268	3870
12B	C	AL	.020	2B	AL	4S-140	.035	3/TQ	Ex	IC	-1	+ 1/2	0	5 1/2	14	5	1912	3295
14B	S	AL	.017	4B	AL	4S-165	.035	3/TQ	Ex	IC	-1	+ 1/2	0	5 1/2	14	5	2008	3395
14B	S	AL	.017	4B	AL	4S-165	.035	3/TQ	Ex	IC	-1	+ 1/2	0	5 1/2	14	5	2265	3485
13B	HO	HO	.025	3B	C	870	.034	3/TQ	Ex	IC	+1	+ 1/2	3/32	7 7/60	16	4		3106
12B	HO	HO	.015	6B	C	870	.034	3/TQ	Ex	IC	+1	+ 1/2	3/32	7 7/60	20	5		3216
12B	HO	HO	.015	6B	C	870	.034	3/TQ	Ex	IC	+1	+ 1/2	3/32	7 7/60	21	5		2986
26.8B	C	AL	.020	TC	C	H10	.032	3/Hy	Ex	IC	+1/2	0	1/8	3 36/60	14	5	2096	3254
33.7B	C	AL	.020	TC	C	H11	.030	3/Hy	Ex	IC	+1/4	0	1/8	3 36/60	19.5	7	2351	3495
14.0B	C	AL	.017	5B	AL	AG5	.035	TQ	Ex	IC	+1/4	0	1/8	3 36/60	21.0	5	2593	3806
8B	HO	HO	.015	5B	C	870	.034	TQ	Ex	IC	-3/4	+ 3/8	1/8	7 1/6	25.2	5		4235
12B	HO	HO	.015	3B	C	870	.034	3/TQ	Ex	IC	-3/4	+ 3/8	1/8	7 1/6	20.0	5		3450
12B	HO	HO	.015	3B	C	870	.034	3/TQ	Ex	IC	-3/4	+ 3/8	1/8	7 1/6	20.0	5		3560
10B	C	DR	.022	4A	AL	A7	.030	3/Hy	Ex	IC	+1/2	0	1/8	6 1/2	14.0	4	2025	3134
12 1/2B	C	DR	.022	4A	AL	A7	.030	3/Hy	Ex	IC	+1/4	0	1/8	6 1/2	17.0	6	2271	3538
14	C	AL	.017	5B	AL	AG5	.035	TQ	Ex	IC	+1/4	0	1/8	6 1/2	20.0	5	2547	3795
5B	Z	LS	.015	11B	C	N8B	.024	3	Ex	IC	+2 1/2	+1	1/8	6 1/2	8	4	1353	1835
10B	C	DR	.022	4A	A	A74	.030	3/Hy	Ex	IC	+1	+ 1/2	1/8	8	12	4	1549	2567
10B	C	DR	.022	4A	A	A74	.030	3/Hy	Ex	IC	+1	+ 1/2	1/8	8	12	4	1821	2606
13.5B	R	DR	.016	5B	AC	44-5	.030	3/Hy	Ex	IC	- 3/8	+ 1/4	3/32	5 51/60	21.5	5	2151	3707
13.5B	R	DR	.016	5B	AC	44-5	.030	3/Hy	Ex	IC	- 3/8	+ 1/4	3/32	5 51/60	21.5	5	2579	3864
14B	C	AL	.016	6B	C	H10	.035	3/TQ	Ex	IC	- 3/4	+ 1/4	1/32	5 5/6	26.5	5	2373	3680
14B	R	DR	.016	6B	AL	AG5	.035	3/TQ	Ex	IC	- 3/4	+ 1/4	1/32	5 5/6	26.5	5	2689	3885
14B	R	DR	.016	6B	C	H10	.035	TQ	Ex	IC	- 3/4	+ 1/4	1/32	5 5/6	27.0	5	3728	4275
12B	C	AL	.020	2B	AL	4S140	.035	3/TQ	Ex	IC	-1	+ 1/2	1/32	5 1/2	14.0	5	1622	3129
14B	C	AL	.018	4B	AL	4S165	.035	3/TQ	Ex	IC	-1	+ 1/2	1/32	5 1/2	20.0	5	1718	3246
	C	DR	.016	5B	AC	44-5	.036	3/Hy	Ex	IC	-1	1/2	1/32		26	5	1972	3511
	C	DR	.016	5B	AC	44-5	.036	3/Hy	Ex	IC	-1	1/2	1/32		26	5	2156	3556
15B	C	AL	.020	2B	C	J7	.031	3/TQ	Ex	IC	-1 3/4	1/2	3/32	6	10	5	1619	2800
11B	S	DR	.013	8B	C	H11	.036	3/TQ	Ex	IC	-1 3/4	1/2	3/32	6	17	6	1738	3095
11B	S	DR	.013	8B	C	H11	.036	3/TQ	Ex	IC	-1 3/4	1/2	3/32	6	17	6	2102	3205
10B	C	AL	.020	4B	C	J8	.030	3/Hy	Ex	IC	+1	+11	1/8	6	13	5	1584	2778

IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves
J - Johnson Carburetor
LS - Lucas
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders
R - Rochester Carburetor
S - Stromberg Carburetor

Se - Semi-elliptic Springs
Sch - Schebler Carburetor
Ste - Stewart Carburetors
SV - Sliding Valves
TA - Torque Arms
TC - Top Center
TH - T-head Engine
TQ - Torque Converter
TT - Torque Tube
Til. - Tillotson Carburetor
Tr - Transverse Springs

VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical and

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MAKE AND MODEL	Wheelbase	Tire Size	Number of Cylinders Bore and Stroke	Displacement	Valve and Cylinder arrangement	Compression ratio	Maximum Brake Horsepower	Horsepower per cu. in.	Number main bearings	Operating Tappet Clearance Intake	Operating Tappet Clearance Exhaut	Intake tappet Clearance, valve timing
Buick 40	122	7.10/15	V8-4.0x3.2	322	VO	8.9	220@4400	.682	5	hy	hy	hy
Buick 60	122	7.60/15	V8-4.0x3.2	322	VO	9.5	255@4400	.782	5	hy	hy	hy
Buick 50	127	7.60/15	V8-4.0x3.2	322	VO	9.5	255@4400	.782	5	hy	hy	hy
Buick 70	127	8.00/15	V8-4.0x3.2	322	VO	9.5	255@4400	.782	5	hy	hy	hy
Cadillac. 6237S	129	8.20/15	V8-4.0x3.625	365	VO	9.75	305@4700	.836	5	hy	hy	hy
Cadillac. 6267S	129	8.20/15	V8-4.0x3.625	365	VO	9.75	305@4700	.836	5	hy	hy	hy
Cadillac. 6267,6219,6239D	129	8.00/15	V8-4.0x3.625	365	VO	9.75	285@4600	.780	5	hy	hy	hy
Cadillac. 6237,6237D	129	8.00/15	V8-4.0x3.625	365	VO	9.75	285@4600	.780	5	hy	hy	hy
Cadillac. 6019	133	8.00/15	V8-4.0x3.625	365	VO	9.75	285@4600	.780	5	hy	hy	hy
Cadillac. 75	149 3/4	8.20/15	V8-4.0x3.625	365	VO	9.75	285@4600	.780	5	hy	hy	hy
Chevrolet Six	115	6.70/15	6-3 9/16x3 15/16	235.5	IO	8.00	140@4200	.595	4	hy	hy	hy
Chevrolet Eight	115	6.70/15	V8-3 3/4x3	265	VO	8.00	162@4400	.611	5	hy	hy	hy
Chevrolet Eight Pow.GL.	115	6.70/15	V8-3 3/4x3	265	VO	9.25	205@4600	.775	5	hy	hy	hy
Chrysler Windsor C-71	126	7.60/15	V8-3.81x3.63	331	VO	8.50	225@4400	.680	5	hy	hy	hy
Chrysler N.Y. C-72	126	8.00/15	V8-3.94x3.63	354	VO	9.00	280@4600	.791	5	hy	hy	hy
Chrysler 300B C-72-300	126	8.00/15	V8-3.94x3.63	354	VO	9.00	280@4600	.791	5	hy	hy	hy
Chrysler Imp. C-70	149 1/2	8.20/15	V8-3.94x3.63	354	VO	9.00	280@4600	.791	5	hy	hy	hy
Chrysler Crow. Imp. C-73	133	8.20/15	V8-3.94x3.63	354	VO	9.00	280@4600	.791	5	hy	hy	hy
Continental	126	8.00/15	V8-4x3 21/32	368.0	VO	9.00	285@4600	.775	5	hy	hy	hy
Corvette	102	6.70/15	V8-3 3/4x3	265	VO	9.25	270@3600	.850	5	.008H	.018H	.008
DeSoto F.dome S23	126	7.60/15	V8-3.72x3.80	330	VO	8.5	230@4400	.697	5	hy	hy	hy
DeSoto F.flite S24	126	7.60/15	V8-3.72x3.80	330	VO	8.5	255@4400	.775	5	hy	hy	hy
Dodge Six D-62-1	120	6.70/15	6-3.25x4.63	230	IL	7.6	131@3800	.570	4	.010H	.010H	.014
Dodge Eight D-63-1	120	7.10/15	V8-3.63x3.256	270	VO	8.0	189@4400	.700	5	hy	hy	hy
Dodge Eight D-63-2	120	7.10/15	V8-3.63x3.80	315	VO	8.0	218@4400	.692	5	hy	hy	hy
Dodge Eight D-63-3	120	7.60/15	V8-3.63x3.80	315	VO	8.0	230@4400		5	hy	hy	hy
Ford Six	115 1/2	6.70/15	6-3.62x3.60	223	IO	8.0	137@4200	.615	4	.019H	.019H	.019H
Ford, Main., Cust. Eight	115 1/2	6.70/15	V8-3.62x3.30	272	VO	8.0	173@4400	.636	5	.019H	.019H	.019H
Ford Fairlane Eight	115 1/2	6.70/15	V8-3.75x3.30	292	VO	8.0	200@4600	.685	5	.019H	.019H	.019H
Hudson Wasp	114 1/4	6.70/15	6-3x4.75	202	IL	7.5	120@4000	.595	4	.010C	.015C	.010C
Hudson Hornet 6	121 1/4	7.10/15	6-3 13/16x4 1/2	308	IL	7.5	165@3800	.535	4	hy	hy	hy
Hudson Hornet V8	121 1/4	7.60/15	V8-4x3 1/2	352	VO	9.5	220@4600	.625	5	hy	hy	hy
Lincoln 73A,73B	126	8.00/15	V8-4x3.66	368	VO	9.0	285@4600	.775	5	hy	hy	hy
Mercury . (3 Models)	119	8.10/15	V8-3.8x3.44	312	VO	8.0	210@4600	.675	5	.019H	.019H	.019H
Nash Amb. 6 5660	121 1/4	7.10/15	6-3.5x4 3/8	252.6	IO	7.6	135@3700	.535	7	.012H	.016H	.016H
Nash Amb. 8 5680	121 1/4	7.60/15	V8-4x3 1/2	352.0	VO	9.55	220@4800	.625	5	hy	hy	hy
Nash State 6 5640	114 1/4	6.70/15	6-3 1/8x4 1/4	195.6	IO	7.47	130@4500	.665	4	.012C	.016C	.015
Oldsmobile 88	122	7.10/15	V8-3 7/8x3 7/16	324.3	VO	9.25	230@4400	.710	5	hy	hy	hy
Oldsmobile Super 88	122	7.60/15	V8-3 7/8x3 7/16	324.3	VO	9.25	240@4400	.740	5	hy	hy	hy
Oldsmobile 98	126	7.60/15	V8-3 7/8x3 7/16	324.3	VO	9.25	240@4400	.740	5	hy	hy	hy
Packard Clip. De. 5640	122	7.60/15	V8-4.0x3.5	352	VO		240@4600		5	hy	hy	hy
Packard Clip. Cust. 5660	122	7.60/15	V8-4.0x3.5	352	VO		275@4600		5	hy	hy	hy
Packard 5680	127	8.00/15	V8-4 1/8x3.5	374	VO	10.	290@4600	.775	5	hy	hy	hy
Packard Carib. 5688	127	8.00/15	V8-4 1/8x3.5	374	VO	10.	310@4600	.829	5	hy	hy	hy
Plymouth Six P28	115	6.70/15	6-3.25x4.63	230	IL	7.6	131@3600	.543	4	.010H	.010H	.014
Plymouth Eight P29	115	6.70/15	V8-3.75x3.13	277	VO	8.0	200@4400	.675	5	hy	hy	hy
Plymouth Eight	115	6.70/15	V8-3.63x3.27	270	VO	8.0	180@4400	.666	5	hy	hy	hy
Pontiac 56-27	122	7.10/15	V8-3.94x3.25	316.6	VO	8.9	205@4600	.650	5	hy	hy	hy
Pontiac 56-28	124	7.10/15	V8-3.94x3.25	316.6	VO	8.9	227@4800	.720	5	hy	hy	hy
Rambler	108	7.10/15	6-3 5/16 x4 1/4	195.6	IL	7.47	120@4200	.605	4	.012H	.016H	.015
Studebaker, Pres. 56H	116 1/2	6.70/15	V8-3 9/16x3 5/8	289.9	VO	7.8	195@4500	.675	4	.026C	.026C	.030
Studebaker Class. Sky.H. 56H	120 1/2	7.10/15	V8-3 9/16x3 5/8	289.9	VO	7.8	195@4500	.675	4	.026C	.026C	.030
Studebaker Champ. 56G	116 1/2	6.40/15	6-3x4 3/8	185.6	L	7.8	101@4000	.545	4	.016C	.016C	.020
Studebaker Gold H. 56J	120 1/2	7.10/15	V8-4x3 1/2	352	VO	9.5	275@4600	.780	5	hy	hy	hy
Studebaker Comm. 56B	116 1/2	6.70/15	V8-3 9/16x3 1/4	259.2	VO	7.8	170@4500	.660	5	.026C	.026C	.030
Thunderbird	102	6.70/15	V8-3 3/4x3.3	312.0	VO	8.40	215@4600	.690	5	.019H	.019H	.019H
Willys Jeep C J	101a	6.00/16	4-3 1/8x4 3/8	134.2	F	6.9	72@4000	.536	3	.018C	.016C	.026
Willys 475	104	6.75/15	4-3 1/8x4 3/8	134.2	F	7.4	75@4000	.560	3	.018C	.016C	.026
Willys 685	104	6.75/15	6-3 1/8x3 1/2	161.0	F	7.6	90@4200	.560	4	.018C	.016C	.026
Willys 6-226-A	108	6.40/15	6-3.312x4 3/8	226.2	L	7.3	115@3650	.516	4	.014C	.014C	.018
Willys Manhattan	118 1/2	6.70/15	6-3.213x4 3/8	226.2	L	7.3	140@3800	.620	4	.014C	.014C	.018

*Applies to cars with conventional transmission.
For Hydramatic cars, intake valve opens 27 deg.B.

ABBREVIATIONS:

A - American Bosch
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
B - Before Top Center
C - Carter Carburetor
CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug
CS - Coil Spring
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D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco-Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs
E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
F - Ford
FA - Ford or American Bosch
FE - Full Elliptic Leaf Spring
FH - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley Carburetor
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement
Hy - Hydramatic Transmission
hy - Hydraulic Tappets
IC - Independent Suspension W/Coil Spring

Tuneup Specifications

Intake valve Opens - deg.	Make of Carburetor	Make Ignition System	Breaker point gap	Breaker point opens-deg.	Spark Plug		Spark Plug Gap	Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Wheel Alignment				Cooling System Capacity, qts.	Capacity Crankcase qt.	Lowest Price Four Door Sedan	Weight, lowest Price Four Door Sedan
					Make	Model						Caster	Camber	Toe-in	King Pin Inclination				
30B	C,S,R	DR	.015	5B	AC	44	.032	3/TQ	IC	CS	CS	- 1/2	+ 1/8	3/32	7	19	6	2166	3790
30B	C,S, R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	- 1/2	+ 1/8	3/32	7	19	6	2717	4000
30B	C,S,R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	- 1/2	+ 1/8	3/32	7	19	6	2927	4200
30B	C,S,R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	- 1/2	+ 1/8	3/32	7	19	6	3148	4280
39B	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	Se	- 1	0	.187	5 5/6	19 1/2	5	3669	4370
39B	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	Se	- 1	0	.187	5 5/6	19 1/2	5	3669	4370
39B	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	Se	- 1	0	.187	5 5/6	19 1/2	5	3669	4370
39B	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	Se	- 1	0	.187	5 5/6	19 1/2	5	3669	4370
39B	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	Se	- 1	0	.187	5 5/6	19 1/2	5	4342	4540
39B	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	Se	- 1	0	.187	5 5/6	22	5	5695	5015
10 1/2B	R	DR	.018	TC	AC	44	.035	3/TQ	Ex	CS	Se	+ 1	+ 1/2	5/32	4	17	5	1675	3195
18B	R	DR	.018	4B	AC	44	.035	3/TQ	Ex	CS	Se	+ 1	+ 1/2	5/32	4	17	4	1767	3170
26 1/2B	R	DR	.018	4B	AC	44	.035	TQ	Ex	CS	Se	+ 1	+ 1/2	5/32	4	17	4	1952	3210
5B	CB	AL	.017	2B	AL	AR-52	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	25	5	2565	3900
15B	C	AL	.017	4B	AL	AGR-42	.035	TQ	Ex	CS	Se	-2	+ 1/4	1/8	5 1/2	26	5	3402	4110
35B	C	AL	.017	4B	AL	AGR-42	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	26	5	3997	
15B	C	AL	.017	4B	AL	AGR-42	.035	TQ	Ex	CS	Se	- 2	+ 1/4	1/8	7	26	4 1/2	4381	4565
15B	C	AL	.017	4B	AL	AGR-42	.035	TQ	Ex	CS	Se	- 2	+ 1/4	1/8,	5 1/2	26	4 1/2	6945	
18B	HO	HO	.015	5B	CH	860	.034	TQ	Ex	CS	Se	-3/4	+3/8	1/16	7 1/5	25.4	5	9510	
21 1/2B	R	DR	.019	4B	AC	14	.036	TQ	Ex	CS	Se	+1	+1/2	5 /32	4	17	4	2934	
4B	CB	AL	.017	8B	AL	AR-51	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	24	4	2393	3855
15B	C	AL	.017	4B	AL	AR-52	.035	TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	24	4	2803	4005
12B	S	AL	.020	2B	AL	AR-80	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	14	5	2029	3295
14B	S	AL	.017	4B	AL	AR-52	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	20	5	2129	3435
11B	S	AL	.017	6B	AL	AR-52	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	21	5	2257	3475
11B	S	AL	.017	6B	AL	AR-52	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	21	5	2359	3520
24B	HO	HO	.025	4B	CH	870	.034	3/TQ	Ex	CS	Se	+ 3/4	+ 1/2	3/32	7 7/60	15 1/2	4	1699	3127
12B	HO	HO	.015	3B	CH	870	.034	3/TQ	Ex	CS	Se	+ 3/4	+ 1/2	3/32	7 7/60	20	5	1792	3238
12B	HO	HO	.015	3B	CH	870	.034	3/TQ	Ex	CS	Se	+ 3/4	+ 1/2	3/32	7 7/60	20	5	1964	3290
26.8B	C	AL	.019	TC	CH	H10	.032	3/Hy	Ex	CS	Se	+ 1/2	0	1/8	3 1/2	14	5	2179	3264
33.7B	C	AL	.019	TC	CH	H11	.030	3/Hy	Ex	CS	Se	+ 1/2	0	1/8	3 1/2	19 1/2	7	2504	3545
14B	C	AL	.016	5B	CH	N18	.035	3/Hy	Ex	CS	Se	+ 1/2	0	1/8	3 1/2	28	5	2986	3862
18B	HO	HO	.015	5B	CH	860	.034	TQ	Ex	CS	Se	- 3/4	+ 3/8	1/16	7 1/5	25.4	5	3821	4289
12B	HO	HO	.015	3B	CH	870	.034	3/TQ	Ex	CS	Se	- 3/4	+ 3/8	1/8	7	20	5	2157	3520
12 1/2B	C	AL	.019	4A	AL	A-7	.030	3/Hy	IC	CS	CS	+ 1/2	0	1/8	6 1/2	18	6	2644	3520
14B	C	AL	.016	5B	CH	N-18	.036	Hy	IC	CS	CS	+ 1/2	0	1/8	6 1/2	28	5	2956	3700
12 1/2B	C	DR	.016	TC	AL	7J	.030	3/Hy	IC	CS	CS	+ 1/2	0	1/8	6 1/2	12	4	2345	3180
11 1/2B	R	DR	.016	5B	AC	44	.030	3/Hy	Ex	CS	Se	- 3/8	+ 1/4	3/16	5 5/6	21 1/2	5	2226	3748
11 1/2B	R	DR	.016	5B	AC	44	.030	3/Hy	Ex	CS	Se	- 3/8	+ 1/4	3/16	5 5/6	21 1/2	5	2363	3768
11 1/2B	R	DR	.016	5B	AC	44	.030	Hy	Ex	CS	Se	- 3/8	+ 1/4	3/16	5 5/6	21 1/2	5	2969	4028
14B	C	AL	.015	5B	AL		.035	3/TQ	Ex	CS	Se	- 1	+ 1/4	1/32	5 5/6	26 1/2	5	2631	4010
14B	C	AL	.015	5B	AL		.035	3/TQ	Ex	CS	Se	- 1	+ 1/4	1/32	5 5/6	26 1/2	5	2820	4070
14B	R	DR	.015	10B	CH	N-18	.035	3/TQ	Ex	CS	Se	- 1	+ 1/4	1/32	5 5/6	27	5	3826	4255
14B	R	DR	.015	10B	CH	N-18	.035	TQ	Ex	CS	Se	- 1	+ 1/4	1/32	5 5/6	27	5	5069	
12B	CB	AL	.020	2B	AL	80	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	14	5	1726	3145
14B	CB	AL	.017	4B	AL	52	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	21	5	1822	3295
14B	CB	AL	.017	4B	AL	52	.035	3/TQ	Ex	CS	Se	- 2	+ 1/4	1/8	5 1/2	20	5	1914	3275
22B*	R	DR	.016	5B	AC	44	.035	3/Hy	Ex	CS	Se	- 1	+ 1/2	1/32.	1 1/3	24.3	5	2060	3496
22B*	R	DR	.016	5B	AC	44	.035	3/Hy	Ex	CS	Se	- 1	+ 1/2	1/32	1 1/3	24.3	5	2167	3486
12 1/2B	C	AL	.016	TC	AL	14	.030	3/Hy	Ex	CS	Se	+1	+1/2	3/32	8	12	4	2025	2868
11B	S	DR	.015	4B	CH	H-11	.035	3/TQ	Ex	CS	Se	- 1 3/4	+ 1/2	3/32	6	18.5	5	2231	3210
11B	C	DR	.015	4B	CH	H-11	.035	3/TQ	Ex	CS	Se	- 1 3/4	+ 1/2	3/32	6	18.5	5	2473	
15B	C	AL	.020	2B	CH	J-7	.030	3/TQ	Ex	CS	Se	- 1 3/4	+ 1/2	3/32	6	12.5	5	1993	2835
14B	C	AL	.015	5B	CH	N-18	.035	3/TQ	Ex	CS	Se	- 1 3/4	+ 1/2	3/32	6	26.5	5	3057	
11B	S	DR	.015	4B	CH	H-11	.035	3/TQ	Ex	CS	Se	- 1 3/4	+ 1/2	3/32	6	18.5	5	2121	3140
12B	HO	HO	.015	3B	CH	870	.034	3/TQ	Ex	CS	Se	-3/4	+3/8	1/16	7	20	5	3102	
9B	C	AL	.020	5B	CH	J-8	.030	3	Ex	Tr	Se	+ 3	+ 1 1/2	.070	7 1/2	12	4		
9B	C	AL	.020	5B	CH	J-8	.030	3	Ex	Tr	Se	+ 1	+ 1 1/2	3/32	5	12	4		
9B	C	AL	.020	5B	CH	J-8	.030	3	Ex	Tr	Se	+ 1	+ 1 1/2	3/32	5	11	5		
10B	C	AL	.020	4B	CH	J-8	.030	3/Hy	Ex	CS	Se	+ 1	+ 1	1/8	6	14	5		
10B	C	AL	.020	4B	CH	J-8	.030	3/Hy	Ex	CS	Se	+ 1	+ 1	1/8	6	14	5		

IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves
J - Johnson Carburetor
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders
R - Rochester Carburetor
S - Stromberg Carburetor
SV - Sliding Valves

Se - Semi-elliptic Springs
Sch - Schebler Carburetor
Ste - Stewart Carburetors
TA - Torque Arms
TC - Top Center
TH - T-head Engine
TQ - Torque Converter
TT - Torque Tube
Til - Tillotson Carburetor
Tr - Transverse Springs

VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical and

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MAKE AND MODEL	Wheelbase	Tire Size	No. of Cylinders Bore & Stroke	Displacement Cu. In.	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower	Horsepower Per Cu. In.	No. of Main Bearings	Operating Tappet Clearance		Intake Tappet Clearance for Valve Timing
										Intake	Exhaust	
Buick Spe. 40	122.0	7.10/15	V8-4 1/8 x 3 13/32	364.0	VO	8.0	250@4400	.687	5	hy	hy	hy
Buick Cent. 60	122.0	7.60/15	V8-4 1/8 x 3 13/32	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy
Buick Super 50	127.5	7.60/15	V8-4 1/8 x 3 13/32	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy
Buick Rdmst. 70	127.5	8.00/15	V8-4 1/8 x 3 13/32	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy
Cadillac 62	129.5	8.00/15	V8-4 x 3 5/8	365.0	VO	10.0	300@4800	.821	5	hy	hy	hy
Cadillac 60	133.0	8.20/15	V8-4 x 3 5/8	365.0	VO	10.0	300@4800	.821	5	hy	hy	hy
Chevrolet Six	115.0	7.50/14	6-3 9/16 x 3 15/16	235.5	IO	8.0	140@4200	.596	4	hy	hy	hy
Chevrolet V-8	115.0	7.50/14	V8-3 3/4 x 3	265.0	VO	8.0	162@4400	.608	5	hy	hy	hy
Chrysler Wind. C-75-1	126.0	8.50/14	V8-3 15/16 x 3 5/8	354.0	VO	9.25	285@4600	.805	5	hy	hy	hy
Chrysler Sar. C-75-2	126.0	8.50/14	V8-3 15/16 x 3 5/8	354.0	VO	9.25	295@4800	.834	5	hy	hy	hy
Chrysler N.Y. C-75	126.0	9.00/14	V8-4 x 3 29/32	392.0	VO	9.25	325@4600	.830	5	hy	hy	hy
Chrysler C300, C76-300	126.0	9.00/14	V8-4 x 3 29/32	392.0	VO	9.25	375@5200	.958	5	.015	.024	.0
Continental 60A	126.0	8.00/15	V8-4 x 3 21/32	368.0	VO	10.0	300@4800	.815	5	hy	hy	hy
Corvette 2934	102.0	6.70/15	V8-3 7/8 x 3	283.0	VO	10.5	220@4800	.778	5	hy	hy	hy
DeSoto Fireswp. S-27	122.0	8.00/14	V8-3 11/16 x 3 51/64	325.0	VO	8.5	245@4400	.755	5	hy	hy	hy
DeSoto Firedome S-25	126.0	8.50/14	V8-3 25/32 x 3 51/64	341.0	VO	9.25	270@4600	.790	5	hy	hy	hy
DeSoto Fireflite S-26	126.0	8.50/14	V8-3 25/32 x 3 51/64	341.0	VO	9.25	295@4600	.365	5	hy	hy	hy
Dodge Six	122.0	7.50/14	6-3 1/4 x 4 5/8	230.0	IL	8.00	138@4000	.600	4	.010H	.010H	.014
Dodge Coron. D66, D67, D70	122.0	7.50/14	V8-3 11/16 x 3 51/64	325.0	VO	8.50	245@4400	.755	5	hy	hy	hy
Dodge Cust. Roy. D67-2	122.0	8.00/14	V8-3 11/16 x 3 51/64	325.0	VO	8.50	260@4400	.800	5	hy	hy	hy
Ford Six Cust.	116.0	7.50/14	6-3 5/8 x 3 39/64	223.0	IO	8.60	144@4200	.645	4	.019H	.019H	.019
Ford Six Fairlane	118.0	7.50/14	6-3 5/8 x 3 39/64	223.0	IO	8.60	144@4200	.645	4	.019H	.019H	.019
Ford V-8, Cust. 300	116.0	7.50/14	V8-3 5/8 x 3 19/64	272.0	VO	8.60	190@4500	.700	5	.019H	.019H	.019
Ford V-8, Fairlane, 500	118.0	7.50/14	V8-3 3/4 x 3 19/64	292.0	VO	9.10	206@4500	.705	5	.019H	.019H	.019
Hudson Hornet 35780	121.3	8.00/14	V8-4 x 3 1/4	327.0	VO	9.00	255@4700	.780	5	hy	hy	hy
Imperial Crown	129.0	9.00/14	V8-4 x 3 29/32	392.0	VO	9.25	325@4600	.829	5	hy	hy	hy
Lincoln Capri, Prem.	126.0	8.00/15	V8-4 x 3 21/32	368.0	VO	10.0	300@4800	.816	5	hy	hy	hy
Mercury Mont., Mtcl.	122.0	8.00/14	V8-3 51/64 x 3 7/16	312.0	VO	9.70	255@4600	.816	5	.019H	.019H	.019
Mercury Turnpike	122.0	8.00/14	V8-4 x 3 21/32	368.0	VO	9.70	290@4600	.789	5	.019H	.019H	.019
Metropolitan 562	85.0	5.20/13	4-2 7/8 x 3 1/2	90.9	IL	7.20	52@4500	.578	3	.015H	.015H	.020
Nash Amb. 5780	121.3	8.00/14	V8-4 x 3 1/4	327.0	VO	9.00	255@4700	.780	5	hy	hy	hy
Olds 88, Sup. 88	122.0	8.50/14	V8-8 x 3 11/16	370.7	VO	9.50	277@4400	.750	5	hy	hy	hy
Olds 98	126.0	8.50/14	V8-8 x 3 11/16	370.7	VO	9.50	277@4400	.750	5	hy	hy	hy
Packard Clip. 57L	120.5	7.60/15	V8-3 9/16 x 3 5/8	289.0	VO	7.50	275@4800	.954	5	.024H	.024H	.030
Plymouth P30	118.0	7.50/14	6-3 1/4 x 4 5/8	230.0	IL	8.00	132@3600	.570	4	.010H	.010H	.014
Plymouth Plaza P31-1	118.0	7.50/14	V8-3 3/4 x 3 1/8	277.0	VO	8.00	197@4400	.712	5	.008H	.018H	.0
Plymouth P31-2, P31-3	118.0	7.50/14	V8-3 29/32 x 3 1/8	301.0	VO	8.50	215@4400	.776	5	.008H	.018H	.0
Plymouth Fury	118.0	8.00/14	V8-3 29/32 x 3 5/16	318.0	VO	9.25	290@5400	.911	5	.008H	.018H	.0
Pontiac	122.0	8.00/14	V8-3 15/16 x 3 9/16	347.0	VO	8.50	227@4600	.614	5	hy	hy	hy
Rambler 5710	108.0	6.40/15	6-3 1/8 x 4 1/4	195.6	IL	8.25	125@4200	.640	4	.012H	.016H	.021
Rambler 5720	108.0	6.70/15	V8-3 1/2 x 3 1/4	250.0	VO	8.00	240@4900	.960	5	.012H	.014H	.020
Studebaker Champ. 57L	116.5	6.40/15	6-3 x 4 3/8	185.6	IL	7.80	101@4000	.543	4	.016C	.016C	.020
Studebaker Com. 57B	116.5	6.70/15	V8-3 9/16 x 3 1/4	259.2	VO	8.30	180@4500	.695	5	.024H	.024H	.030
Studebaker Pres. 57H	116.5	6.70/15	V8-3 9/16 x 3 5/8	289.0	VO	8.30	210@4500	.728	5	.024H	.024H	.030
Studebaker Gold. Hawk	120.5	7.10/15	V8-3 9/16 x 3 5/8	289.0	VO	7.50	275@4800	.953	5	.024H	.024H	.030

ABBREVIATIONS

A - American Bosch
AC - AC Spark Plug
AO - Automatic Optional
AL - Auto Lite
Ac - Air-Cooled Engine
a - Others Also
b - Left side + 3/8, Right side 0
B - Before Top Center
C - Carter Carburetor
CB - Carter Ball & Ball Type
CG - Chandler Grove
CH - Champion Spark Plug

CS - Coil Spring
CaS - Cantilever Spring
D - Dubonnet Front Suspension
DI - Diamond Ignition System
DL - Detroit Lubricator Carburetor
DR - Delco Remy Ignition
DeJ - DeJon Ignition
D.Tr - Double Transverse Springs
E-V - Electric & Vacuum Operated
Ex - Exposed Propeller Shaft
FO - Ford
FA - Ford or American Bosch

FE - Full Elliptic Leaf Spring
F H - F-Head Engine
Fm - Fluidmatic Transmission
H - With engine at operating Temp.
HO - Holley
HT - Hydraulically Operated Transmission
HV - Horizontal Valve Arrangement
Hy - Hydramatic Transmission
hy - Hydraulic Tappets
IC - Independent Suspension W/Coil Spring
IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves

Tuneup Specifications

Intake Valve Opens - Deg.	Carburetor Make	Ignition System Make	Breaker Point Gap	Spark Plugs			Automatic Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Wheel Alignment				Cooling System Capacity Without Heater	Crankcase Capacity Qts	Lowest Price Four Door Sedan	Weight, Lowest Price Four Door Sedan	Breaker Points Open - Deg.
				Make	Model	Gap					Caster	Camber	Toe-In	King Pin Inclination					
25.0B	C, S	DR	.015	AC	44	.033	TQ	IC	CS	CS	-1 3/4	+1/2	1/16	7@52° 32'	16-1/2	5	2412	3955	5B
34.0B	C, R	DR	.015	AC	44	.033	TQ	IC	CS	CS	-1 3/4	+1/2	1/16	7@52° 32'	16-1/2	5	2932	4137	5B
34.0B	C, R	DR	.015	AC	44	.033	TQ	IC	CS	CS	-1 3/4	+1/2	1/16	7@52° 32'	16-1/2	5	3343	4356	5B
34.0B	C, R	DR	.015	AC	44	.033	TQ	IC	CS	CS	-1 3/4	+1/2	1/16	7@52° 32'	16-1/2	5	3680	4469	5B
36.0B	C, R	DR	.016	AC	44	.035	Hy	Ex	CS	Se	-1	0	3/16	4@0°	19-1/2	5	4372	4595	5B-400
36.0B	C, R	DR	.016	AC	44	.035	Hy	Ex	CS	Se	-1	0	3/16	4@0°	19-1/2	5	5124	4755	5B-400
10.5B	R	DR	.019	AC	44	.036	TQ	Ex	CS	Se	+1	+1/2	1/8	4	16	5	1850	3250	TC-475
18.0B	R	DR	.017	AC	44	.036	TQ	Ex	CS	Se	+1	+1/2	1/8	4	16	5	1950	3281	4B-475
13.0B	C	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	21	5	2811	3995	6B-500
13.0B	C	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	21	5	3392	4165	6B-500
15.0B	C	AL	.017	AL	AGR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	24	5	3809	4315	6B-500
35.0B	C	AL	.017	AL	-	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	24	5	4515	4235	6B-500
18.0B	C	HO	.015	CH	860	.034	TQ	Ex	CS	Se	+1	+3/8	1/8	7° 10'@45'	20	5	8938	4797	5B-500
12.5B	C, R	DR	.018	AC	44	.035	TQ	Ex	CS	Se	+1/2	+1/2	1/16	4	23	5	3176	2730	4B-475
10.0B	S	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	16	5	2529	3675	6B-500
15.0B	C	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	2692	3955	6B-500
15.0B	C	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	3179	4025	6B-500
12.0B	S	AL	.017	AL	AR-51	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	13	5	2162	3400	TC-500
10.0B	S	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	2337	3620	6B-500
10.0B	S	AL	.017	AL	AR-42	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	2637	3690	6B-500
17.0B	HO	HO	.025	CH	870	.034	TQ	Ex	CS	Se	+1	+5/8	1/16	7° 1'@45	15	4	1865	3250	4B-800
17.0B	HO	HO	.025	CH	870	.034	TQ	Ex	CS	Se	+1	+5/8	1/16	7°1' @45	15	5	2092	3425	4B-800
18.0B	FO	HO	.015	CH	870	.034	TQ	Ex	CS	Se	+1	+5/8	1/16	7° 1'@45	19	5	1958	3267	3B
18.0B	FO	HO	.015	CH	870	.034	TQ	Ex	CS	Se	+1	+5/8	1/16	7° 1'@45	19	5	2185	3437	3B
12.5B	C	DR	.016	AL	AL-7-J	.035	Hy	IC	CS	CS	+1/2	0	1/8	7° 1'@45	19	5	2520	3631	5B
15.0B	C	AL	.017	AL	AGR-42	.035	TQ	Ex	CS	Se	-3/4	b	1/8	6-1/2	24	5	-	-	6B-500
18.0B	C	HO	.015	CH	860	.034	TQ	Ex	CS	Se	-1/4	+3/8	3/32	7° 12' 14"	23	5	4339	4595	5B
18.0B	C, HO	HO, FO	.015	CH	860	.034	TQ	Ex	CS	Se	-3/4	+3/8	1/8	7°	20	5	2417	3915	3B
18.0B	C, HO	HO, FO	.015	CH	860	.034	TQ	Ex	CS	Se	-3/4	+3/8	1/8	7°	20	5	3537	4015	6B
5.0B	Z	LU	.015	CH	N-8-B	.024	-	Ex	CS	Se	+2 1/2	+1	0	6-1/2	7	4	1406	1825	11B
12.5B	C	DR	.016	AL	AL-7-J	.035	Hy	IC	CS	CS	+1/2	0	1/8	6-1/2	19	5	2520	3639	TC
13.5B	R	DR	.016	AC	44	.030	Hy	Ex	CS	Se	+3/8	+1/4	1/16	7° @ 0°	20	5	2538	4000	5B-850
13.5B	R	DR	.016	AC	44	.030	Hy	Ex	CS	Se	+3/8	+1/4	1/16	7° @ 0°	20	5	3396	4322	5B-850
11B	S	DR	.016	CH	H-10	.036	TQ	Ex	CS	Se	-1 3/4	+1/2	1/16	6° @ 0°	17	5	2933	3570	4B-600
12.0B	C	AL	.020	AL	AR-52	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	13	5	1877	3305	TC-500
8.0B	C	AL	.017	AL	AR-52	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	1970	3405	8B-500
8.0B	C	AL	.017	AL	AR-52	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	2207	3475	8B-500
8.0B	C	AL	.017	AL	AR-52	.035	TQ	Ex	TB	Se	-3/4	b	1/8	6-1/2	20	5	2686	3595	8B-500
22.0B	R	DR	.016	AC	45	.036	Hy	Ex	CS	Se	-1	+1/2	0	1° 20' @ 0°	22	5	2293	3560	6B-450
12.5B	C	DR	.016	AL	AL-7-J	.035	Hy	IC	CS	CS	+1/4	0	1/8	6° 11"	10	4	1757	2911	5B
12.5B	C	DR	.016	AL	AL-7-J	.035	Hy	IC	CS	CS	+1/4	0	1/8	6° 11"	20	5	2095	3259	5B
15.0B	C	AL	.020	CH	J-7	.031	TQ	Ex	CS	Se	-1 3/4	+1/2	1/16	6° @ 0	11	5	1868	2785	2B-550
11.0B	S	DR	.016	CH	H-11	.036	TQ	Ex	CS	Se	-1 3/4	+1/2	1/16	6° @ 0	17	5	1976	3105	4B
11.0B	S	DR	.016	CH	H-11	.036	TQ	Ex	CS	Se	-1 3/4	+1/2	1/16	6° @ 0	17	5	2193	3205	4B
11.0B	S	DR	.016	CH	H-10	.036	TQ	Ex	CS	Se	-1 3/4	+1/2	1/16	6° @ 0	17	5	2912	3400	4B

J - Johnson Carburetor
LU - Lucas
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders
R - Rochester Carburetor
S - Stromberg Carburetor
SV - Sliding Valves
Se - Semi-elliptic Springs
Sch - Schebler Carburetor

Ste - Stewart Carburetors
TA - Torque Arms
TB - Torsion Bar
TC - Top Center
TH - T-Head Engine
TQ - Torque Converter
TT - Torque Tube
Til - Tillotson Carburetor
Tr - Transverse Springs
VL - V-engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift

Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic Springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical and

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MAKE AND MODEL	Wheelbase	Tire Size	No. of Cylinders Bore & Stroke.	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower	Horsepower per Cu. In.	No. of Main Bearings	Operating Tappet Clearance		Intake Tappet Clearance for Valve Timing	Intake Valve Opens - Deg.
										Intake	Exhaust		
Buick 40	122.0	7.10/15	V8-4.125 x 3.4	364.0	VO	9.5	250@4400	.687	5	hy	hy	hy	25
Buick 60	122.0	7.60/15	V8-4.125 x 3.4	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy	34
Buick 50	127.5	7.60/15	V8-4.125 x 3.4	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy	34
Buick 70	127.5	8.00/15	V8-4.125 x 3.4	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy	34
Buick 700	127.5	8.00/15	V8-4.125 x 3.4	364.0	VO	10.0	300@4600	.825	5	hy	hy	hy	34
Cadillac 62	129.5	8.00/15	V8-4.00 x 3.62	365.0	VO	10.25	310@4800	.85	5	hy	hy	hy	39
Cadillac 60	133.0	8.00/15	V8-4.00 x 3.62	365.0	VO	10.25	310@4800	.85	5	hy	hy	hy	39
Cadillac 75	149.7	8.20/15	V8-4.00 x 3.62	365.0	VO	10.25	310@4800	.85	5	hy	hy	hy	39
Chevrolet Six	117.5	7.50/14	6-3.56 x 3.94	235.5	IO	8.25	145@4200	.62	4	hy	hy	hy	10-1/2
Chevrolet V-8	117.5	7.50/14	V8-3.875 x 3.00	283	VO	8.5	185@4600	.65	5	hy	hy	hy	12-1/2
Chevrolet V-8	117.5	7.50/14	V8-4.125 x 3.25	348	VO	9.5	250@4400	.72	5	hy	hy	hy	29-3/4
Chrysler Wind.	122	8.00/14	V8-3.94 x 3.63	354	VO	10.0	290@4600	.82	5	hy	hy	hy	13
Chrysler Sar.	126	8.50/14	V8-3.94 x 3.63	354	VO	10.0	310@4600	.87	5	hy	hy	hy	15
Chrysler 300D, N.Y.	126	9.00/14	V8-4.0 x 3.9	392	VO	10.0	345@4600	.88	5	hy	hy	hy	35
Continental	131	9.00/14	V8-4.3 x 3.7	430	VO	10.5	375@4800	.87	5	hy	hy	hy	27
Corvette	102	6.70/15	V8-3.875 x 3.0	283	VO	9.5	*250@5000	.87	5	hy	hy	hy	12-1/2
De Soto-Firesweep	122	8.00/14	V8-4.06 x 3.38	350	VO	10.0	280@4600	.80	5	hy	hy	hy	15
De Soto-Firedome	126	8.50/14	V8-4.12 x 3.38	361	VO	10.0	295@4600	.82	5	hy	hy	hy	15
De Soto-Fireflite	126	8.50/14	V8-4.12 x 3.38	361	VO	10.0	305@4600	.85	5	hy	hy	hy	15
De Soto-Adventurer	126	8.50/14	V8-4.12 x 3.38	361	VO	10.25	345@5000	.96	5	hy	hy	hy	20
Dodge Six	122	7.50/14	6-3.25 x 4.63	230	IL	8.0	138@4000	.60	4	.010H	.010H	.012	12
Dodge Coronet	122	7.50/14	V8-3.69 x 3.80	325	VO	8.5	252@4400	.78	5	hy	hy	hy	10
Dodge Royal	122	8.00/14	V8-3.69 x 3.80	325	VO	8.5	295@4600	.85	5	hy	hy	hy	15
Dodge Custom Royal	122	8.00/14	V8-4.06 x 3.38	350	VO	10.0	305@4600	.85	5	hy	hy	hy	15
Dodge Custom Sierra	122	8.00/14	V8-4.06 x 3.38	350	VO	10.0	305@4600	.85	5	hy	hy	hy	15
Dodge D500	122	8.00/14	V8-4.12 x 3.38	361	VO	10.0	305@4600	.85	5	hy	hy	hy	15
Edsel, Ranger	118	8.00/14	V8-4.05 x 3.50	361	VO	10.5	303@4600	.84	5	hy	hy	hy	17
Edsel, Pacer	118	8.00/14	V8-4.05 x 3.50	361	VO	10.5	303@4600	.84	5	hy	hy	hy	17
Edsel, Corsair	124	8.50/14	V8-4.20 x 3.70	410	VO	10.5	345@4600	.84	5	hy	hy	hy	27
Edsel, Citation	124	8.50/14	V8-4.20 x 3.70	410	VO	10.5	345@4600	.84	5	hy	hy	hy	27
Ford Six	116	7.50/14	I-6-3.6250x3.6093	223	IO	8.6	145@4200	.65	4	.019H	.019H	.019	17
Ford-300	116	7.50/14	V8-3.75 x 3.30	292	VO	9.1	205@4500	.70	5	.019H	.019H	18	18
Ford Fairlane	118	7.50/14	V8-4.00 x 3.30	332	VO	9.5	265@4600	.72	5	.019H	.019H	18	18
Ford - 500	118	7.50/14	V8-4.00 x 3.50	352	VO	10.2	300@4600	.85	5	.026H	.026H	21	21
Imperial	129	9.50/14	V8-4.00 x 3.90	392	VO	10.0	345@4600	.88	5	hy	hy	hy	15
Mercury, Mont. M.C.	122	8.00/14	V8-4.3 x 3.30	383	VO	10.5	330@4800	.81	5	hy	hy	hy	34
Mercury, Park La.	125	8.50/14	V8-4.3 x 3.70	430	VO	10.5	360@4600	.84	5	hy	hy	hy	27
Metropolitan	85	5.20/13	4-2 7/8 x 3.50	90.9	IO	7.20	52@4500	.57	3	.015C	.015C	.015C	-
Oldsmobile 88	122-1/2	8.50/14	V8-4 x 3.68	371	VO	10.1	265@4400	.72	5	hy	hy	hy	16
Oldsmobile, Sup. 88	122-1/2	8.50/14	V8-4 x 3.68	371	VO	10.1	305@4600	.82	5	hy	hy	hy	16
Oldsmobile 98	126-1/2	8.50/14	V8-4 x 3.68	371	VO	10.1	305@4600	.82	5	hy	hy	hy	16
Packard Hawk.	120-1/2	8.00/14	V8-3 9/16 x 3 5/8	289	VO	7.8	275@4800	.95	5	.024H	.024H	.026H	11
Plymouth Six	118	7.50/14	6-3.25 x 4.63	230	IL	8.0	132@3600	.57	4	.010H	.010H	.010	12
Plymouth Plaza	118	7.50/14	V8-3.91 x 3.31	318	VO	9.0	225@4400	.71	5	.012H	.018H	.010	8
Plymouth Sav., Bel.	122	7.50/14	V8-3.91 x 3.31	318	VO	9.0	225@4400	.71	5	.012H	.018H	.010	8
Plymouth Fury	118	7.50/14	V8-3.91 x 3.31	318	VO	9.25	290@5200	.91	5	.012H	.018H	.010	17
Plymouth Com.	122	7.50/14	V8-4.06 x 3.38	350	VO	10.0	305@5000	.87	5	hy	hy	hy	15
Pontiac Chief	122	8.00/14	V8-4.06 x 3.56	370	VO	8.6	240@4500	.65	5	hy	hy	hy	22d
Pontiac Sup. Chief	124	8.00/14	V8-4.06 x 3.56	370	VO	8.6	255@4500	.69	5	hy	hy	hy	22d
Rambler Six	108	6.40/15	6-3.125 x 4.25	195	IO	8.7	127@4200	.65	4	.012	.016	.012	12-1/2
Rambler Rebel	108	7.50/14	V8-3.5 x 3.25	250	VO	8.7	215@4900	.86	5	.012	.016	.012	12-1/2
Rambler Amb.	117	8.00/14	V8-4 x 3.25	327	VO	9.7	270@4700	.83	5	hy	hy	hy	12-1/2
Studebaker Champ. D1	116-1/2	6.40/15	6-3 x 4.37	185	IL	7.8	101@4000	.55	4	.016C	.016C	.016C	15
Studebaker Champ.	120-1/2	6.40/15	6-3 x 4.37	185	IL	7.8	101@4000	.55	4	.016C	.016C	.016C	15
Studebaker Comm.	116-1/2	7.50/14	V8-3 9/16 x 3 1/4	259	VO	8.3	180@4500	.70	5	.024H	.024H	.026C	11
Studebaker Pres.	120-1/2	8.00/14	V8-3 9/16 x 3 5/8	289	VO	8.3	225@4500	.78	5	.024H	.024H	.026C	11
Studebaker Gold. Hawk	120-1/2	8.00/14	V8-3 9/16 x 3 5/8	289	VO	7.8	275@4800	.95	5	.024H	.024H	.026C	11

*with fuel injection

ABBREVIATIONS

A	- American Bosch
AC	- AC Spark Plug
AO	- Automatic Optional
AL	- Auto Lite
Ac	- Air-Cooled Engine
a	- Others Also
b	- Left side + 3/8, Right side 0
B	- Before Top Center
C	- Carter Carburetor
CB	- Carter Ball & Ball Type
CG	- Chandler Grove
CH	- Champion Spark Plug
CS	- Coil Spring
CaS	- Cantilever Spring
d	- Applies to Manual Transmission cars, for Hydramatic cars, 30 deg. B.T.C.
D	- Dubonnet Front Suspension
DI	- Diamond Ignition System
DL	- Detroit Lubricator Carburetor
DR	- Delco Remy Ignition
DeJ	- DeJon Ignition
D.Tr	- Double Transverse Springs
e	- Fuel Injection Optional
E-V	- Electric & Vacuum Operated
Ex	- Exposed Propeller Shaft
FO	- Ford
FA	- Ford or American Bosch
FE	- Full Elliptic Leaf Spring
FH	- F-Head Engine
Fm	- Fluidmatic Transmission
H	- With engine at operating Temp.
HO	- Holley
HT	- Hydraulically Operated Transmission
HV	- Horizontal Valve Arrangement
Hy	- Hydramatic Transmission
hy	- Hydraulic Tappets

Tuneup Specifications

Carburetor Make	Make of Ignition System	Breaker Point Gap	Breaker Points Open - Deg.	Spark Plugs			Automatic Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Wheel Alignment			King Pin Inclination	Cooling System Capacity -Qts. Without Heater	Crankcase Capacity Qts.
				Make	Model	Gap					Caster	Camber	Toe-In			
C, S	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	-3/4	+22'	1/16	7@0°52'	16 1/2	5
C, R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	-3/4	+22'	1/16	7@0°52'	16 1/2	5
C, R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	-3/4	+22'	1/16	7@0°52'	16 1/2	5
C, R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	-3/4	+22'	1/16	7@0°52'	16 1/2	5
C, R	DR	.015	5B	AC	44	.032	TQ	IC	CS	CS	-3/4	+22'	1/16	7°@0°52'	16 1/2	5
C, R	DR	.016	5B	AC	44	.035	HY	Ex	CS	CS	-1	+3/16	1/16	4	20.7	5
C, R	DR	.016	5B	AC	44	.035	HY	Ex	CS	CS	-1	+3/16	1/16	4	20.7	5
C, R	DR	.016	5B	AC	44	.035	HY	Ex	CS	CS	-1	+3/16	1/16	4	21.8	5
R	DR	.018	TC	AC	44	.035	TQ	Ex	CS	CS	+1	+1/2	1/8	4	16	5
R	DR	.018	4B	AC	44	.035	TQ	Ex	CS	CS	+1	+1/2	1/8	4	16	4
C, R	DR	.018	4B	AC	44	.035	TQ	Ex	CS	CS	+1	+1/2	1/8	4	22	4
C	AL	.015	8B	AL	AR42	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	22	4
C	AL	.015	6B	AL	AR42	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	22	4
C	AL	.015	6B	AL	AGR42	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	25	5
HO	F	.015	6B	CH	F-11-Y	.032	TQ	Ex	CS	CS	-1/2	+1/2	1/8	7 1/4	26	5
C	DR	.018	4B	AC	44	.035	TQ	Ex	CS	Se	+2 1/4	+1/2	1/16	4	16	5
C	AL	.015	6B	AL	AR42	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	16	4
C	AL	.015	6B	AL	AR42	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	16	4
C	AL	.015	6B	AL	AR42	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	16	4
C	AL	.015	8B	AL	AR32	.035	TQ	Ex	TB	Se	-3/4	+1/4	1/8	6 1/2°	16	4
S	AL	.022	2B	AL	AR51	.035	TQ	Ex	TB	Se	+1/4	+1/4	1/8	6 1/2°	13	5
S	AL	.015	6B	AL	AGR42	.035	TQ	Ex	TB	Se	+1/4	+1/4	1/8	6 1/2°	20	5
C	AL	.015	6B	AL	AR42	.035	TQ	Ex	TB	Se	+1/4	+1/4	1/8	6 1/2°	20	5
C	AL	.015	6B	AL	AR32	.035	TQ	Ex	TB	Se	+1/4	+1/4	1/8	6 1/2°	20	4
C	AL	.015	8B	AL	AR32	.035	TQ	Ex	TB	Se	+1/4	+1/4	1/8	6 1/2°	16	4
C	AL	.015-.022	8B	AL	AR32	.035	TQ	Ex	TB	Se	+1/4	+1/4	1/8	6 1/2°	16	4
FO or HO	FO	.015	7B	CH	F-11-Y	.035	TQ	Ex	CS	Se	30'to 1°30'	30'to 1°30'	.03	7°-0'	18.5	5
FO or HO	FO	.015	7B	CH	F-11-Y	.035	TQ	Ex	CS	Se	30'to1°30'	30'to 1°3'	.03	7°-0'	18.5	5
HO	FO	.015	7B	CH	F-11-Y	.035	TQ	Ex	CS	Se	0° to 1°	0° to 45'	.06	7°-0'	22	5
HO	FO	.015	7B	CH	F-11-Y	.035	TQ	Ex	CS	Se	0° to 1°	0° to 45'	.06	7°-0'	22	5
HO	HO-FO	.025	4B-6B	CH	870	.035	TQ	Ex	CS	Se	1/2°-1 1/2°	1/2°-1 1/2°	1/16	7°1'at 45	15	4
FO or HO	HO-FO	.015	6° B	CH	F-11-Y	.035	TQ	Ex	CS	Se	+30'	45'	+1°	7° 7'	19	5
HO	FO	.015	6° B	CH	F-11-Y	.035	TQ	Ex	CS	Se	+30'	45'	+1°	7° 7'	19	5
FO or C	FO	.015	6° B	CH	F-11-Y	.035	TQ	Ex	CS	Se	+30'	45'	+1°	7° 7'	19	5
C	AL	.015	6B	AL	AGR42	.035	TQ	Ex	CS	Se	0	0	1/16	6 1/2	25	5
HO	FO	.015	4B	CH	860	.035	TQ	Ex	CS	Se	-1 1/4	-20'	1/8	7	21.5	5
HO	FO	.015	7B	CH	860	.035	TQ	Ex	CS	Se	-1 1/4	-20'	1/8	7	2.5	5
Z	-	.015	11B	-	-	.024	TQ	Ex	CS	Se	+2 1/2	+1	1/16	6 1/2	8	4
R	DR	.015	2B	AC	44	.030	HY	Ex	CS	Se	-1/2	+1/4	1/16	7	21	4
R	DR	.015	2B	AC	44	.030	HY	Ex	CS	Se	-1/2	+1/4	1/16	7	21	4
R	DR	.016	2B	AC	44	.030	HY	Ex	CS	Se	-1/2	+1/4	1/16	7	21	4
S	DR	.015	4B	CH	H18Y	.035	TQ	Ex	CS	CS	-1 3/4	+1/2	3/16	6	18.5	5
C	AL	.020	2B	AL	AR51	.035	TQ	Ex	TB	Se	0	0	1/8	6 1/2	14	5
S	AL	.015	10B	AL	AR42	.035	TQ	Ex	TB	Se	0	0	1/8	6 1/2	21	5
S	AL	.015	10B	AL	AR42	.035	TQ	Ex	TB	Se	0	0	1/8	6 1/2	21	5
S	AL	.015	8B	AL	AR42	.035	TQ	Ex	TB	Se	0	0	1/8	6 1/2	21	5
-	AL	.015	8B	AL	AR32	.035	TQ	Ex	TB	Se	0	0	1/8	6 1/2	17	5
C(e)	DR	.016	6B	AC	45	.035	HY	Ex	CS	CS	-1/2	+1/2	1/32	4°-50'	22.3	5
C(e)	DR	.016	6B	AC	45	.035	HY	Ex	CS	CS	-1/2	+1/2	1/32	4°-50'	22.3	5
C	DR	.016	10	AL	7J	.035	TQ	IC	CS	CS	+1/4	0	1/8	6 1/6	11	4
HO	DR	.016	17-1/3	AL	7J	.035	TQ	IC	CS	CS	+1/4	0	1/8	6 1/6	21	4
HO	DR	.016	15-1/3	AL	7J	.035	TQ	IC	CS	CS	+1/4	0	1/8	6 1/6	20	4
C	AL	.020	5B	CH	7J	.030	TQ	Ex	CS	Se	-1 3/4	+1/2	3/16	6	12.5	5
C	AL	.020	5B	CH	7J	.030	TQ	Ex	CS	Se	-1 3/4	+1/2	3/16	6	12.5	5
S	DR	.015	4B	CH	H18Y	.035	TQ	Ex	CS	CS	-1 3/4	+1/2	3/16	6	18.5	5
C	DR	.015	4B	CH	H18Y	.035	TQ	Ex	CS	CS	-1 3/4	+1/2	3/16	6	18.5	5
S	DR	.015	4B	CH	H18Y	.035	TQ	Ex	CS	CS	-1 3/4	+1/2	3/16	6	18.5	5

IC - Independent Suspension W-Coil Spring
IL - In Line Engine with "L" Head
IO - In Line Engine with Overhead Valves
J - Johnson Carburetor
LU - Lucas
M - Marvel Carburetor
NE - Northeast Ignition
O - Optional
Oh - Overhead Valves & Cams
Op - Opposed Cylinders
R - Rochester Carburetor
S - Stromberg Carburetor

SV - Sliding Valves
Se - Semi-elliptic Springs
Sch - Schebler Carburetor
Ste - Stewart Carburetors
TA - Torque Arms
TB - Torsion Bar
TC - Top Center
TH - T-Head Engine
TQ - Torque Converter
TT - Torque Tube
Til - Tillotson Carburetor
Tr - Transverse Springs

VL - V-Engine with "L" Head
VO - V-engine with Overhead Valves
Vac - Vacuum Operated Shift
Var - Various
Z - Zenith Carburetor
1/4 - Quarter elliptic Springs
3/4 - Three-quarter elliptic Springs
3 - Three Speed Conventional Transmission
30 - Three Speed Transmission with Overdrive
4 - Four Speed Conventional Transmission

Official Mechanical and

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MAKE AND MODEL	Wheelbase	Tire Size	No. of Cylinder Bore & Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horsepower	Horsepower per Cu. In.	No. of Main Bearings	Operating Tappet Clearance In-take	Operating Tappet Clearance Ex-haust
Buick LeSabre	123	7.60/15	V8-4.125 x 3.4	364	VO	10.5	250@4400	.687	5	hy	hy
Buick Invicta	123	8.00/15	V8-4.1875 x 3.64	401	VO	10.5	325@4400	.810	5	hy	hy
Buick Electra	126.3	8.00/15	V8-4.1875 x 3.64	401	VO	10.5	325@4400	.810	5	hy	hy
Cadillac 62	130	8.00/15	V8-4.0 x 3.875	390	VO	10.5	325@4800	.832	5	hy	hy
Cadillac 60	130	8.00/15	V8-4.0 x 3.875	390	VO	10.5	325@4800	.832	5	hy	hy
Cadillac 75	149.8	8.20/15	V8-4.0 x 3.875	390	VO	10.5	325@4800	.832	5	hy	hy
Cadillac El Dor.	130	8.00/15	V8-4.0 x 3.875	390	VO	10.5	345@4800	.885	5	hy	hy
Chevrolet Six	119	7.50/14	6-3.562 x 3.94	235	IO	8.25	135@4000	.573	4	hy	hy
Chevrolet 283	119	7.50/14	V8-3.875 x 3.00	283	VO	8.5	185@4600	.654	5	hy	hy
Chevrolet 348	119	7.50/14	V8-4.125 x 3.25	348	VO	9.5	250@4400	.719	5	hy	hy
Corvette 1 Carb.	102	6.70/15	V8-3.875 x 3.00	283	VO	9.5	230@4800	.813	5	hy	hy
Corvette, F. Inj.	102	6.70/15	V8-3.875 x 3.00	283	VO	9.5	250@5000	.884	5	hy	hy
Corvette 2 Carb.	102	6.70/15	V8-3.875 x 3.00	283	VO	9.5	245@5000	.868	5	hy	hy
Chrysler Wind.	126	8.00/14	V8-4.031 x 3.75	383	VO	10.0	305@4600	.796	5	hy	hy
Chrysler Sara.	126	8.50/14	V8-4.031 x 3.75	383	VO	10.0	325@4600	.849	5	hy	hy
Chrysler N. Y.	126	8.50/14	V8-4.188 x 3.75	413	VO	10.0	350@4600	.847	5	hy	hy
Chrysler 300	126	8.50/14	V8-4.188 x 3.75	413	VO	10.0	380@5000	.920	5	hy	hy
Chrysler Imp.	129	9.00/14	V8-4.188 x 3.75	413	VO	10.0	350@4600	.803	5	hy	hy
DeSoto F. Sweep	122	8.00/14	V8-4.125 x 3.38	361	VO	10.0	290@4600	.803	5	hy	hy
DeSoto F. Dome	126	8.50/14	V8-4.250 x 3.38	383	VO	10.0	305@4600	.796	5	hy	hy
DeSoto F. Flite	126	8.50/14	V8-4.250 x 3.38	383	VO	10.0	325@4600	.849	5	hy	hy
DeSoto Advent.	126	8.50/14	V8-4.250 x 3.38	383	VO	10.0	350@5000	.914	5	hy	hy
Dodge Six	122	7.50/14	6-3.25 x 4.625	230	IL	8.0	135@3600	.587	4	.011C	.014C
Dodge Coronet	122	8.00/14	V8-3.953. x 3.312	326	VO	10.1	255@4400	.782	5	hy	hy
Dodge Custom	122	8.00/14	V8-4.125 x 3.375	361	VO	10.1	305@4600	.845	5	hy	hy
Dodge Roy. Sier.	122	8.00/14	V8-4.125 x 3.375	361	VO	10.1	295@4600	.817	5	hy	hy
Dodge D500	122	8.00/14	V8-4.25 x 3.375	383	VO	10.0	320@4600	.835	5	hy	hy
Dodge D500 Super	122	8.00/14	V8-4.25 x 3.375	383	VO	10.0	345@500	.900	5	hy	hy
Edsel Six	120	7.50/14	6-3.625 x 3.593	223	VO	8.4	145@4000	.650	4	.019C	.019C
Edsel 292	120	8.00/14	V8-3.75 x 3.298	292	VO	8.8	200@4400	.685	5	.019C	.019C
Edsel 332	120	8.00/14	V8-4.00 x 3.296	332	VO	8.9	225@4000	.678	5	hy	hy
Edsel 361	120	8.00/14	V8-4.046 x 3.50	361	VO	9.6	303@4600	.837	5	hy	hy
Ford Six	118	7.50/14	6-3.625 x 3.593	223	VO	8.4	145@4000	.650	4	.019C	.019C
Ford 292	118	7.50/14	V8-3.75 x 3.296	292	VO	8.8	200@4400	.685	5	.018C	.018C
Ford 332	118	7.50/14	V8-4.00 x 3.296	332	VO	8.9	225@4000	.678	5	hy	hy
Ford 352	118	7.50/14	V8-4.00 x 3.50	352	VO	9.6	300@4600	.852	5	hy	hy
F. Thunderbird Std.	118	8.00/14	V8-4.00 x 3.50	352	VO	9.6	300@4600	.852	5	hy	hy
F. Thunderbird Opt.	118	8.00/14	V8-4.30 x 3.70	430	VO	10.1	350@4800	.814	5	hy	hy
Lincoln 1959	131	9.50/14	V8-4.30 x 3.70	430	VO	10.5	375@4800	.870	5	hy	hy
Mercury 312	126	8.00/14	V8-3.80 x 3.44	312	VO	9.6	210@4400	.673	5	.019H	.019H
Mercury 383	126	8.50/14	V8-4.30 x 3.30	383	VO	10.0	322@4600	.841	5	hy	hy
Mercury 430	126	8.50/14	V8-4.30 x 3.70	430	VO	10.0	345@4400	.802	5	hy	hy
Oldsmobile Dyn 88	123	8.50/14	V8-4 x 3.687	371	VO	9.75	270@4600	.728	5	hy	hy
Oldsmobile Sup 88	123	9.00/14	V8-4.125 x 3.687	394	VO	9.75	315@4600	.799	5	hy	hy
Oldsmobile 98	126.3	9.00/14	V8-4.125 x 3.687	394	VO	9.75	315@4600	.799	5	hy	hy
Plymouth Six	118	7.50/14	6-3 1/4 x 4.625	230	IL	8.0	132@3600	.574	4	.010H	.012H
Plymouth MP 2	118	7.50/14	V8-3.906x 3.312	318	VO	9.0	230@4400	.723	5	.010H	.018H
Plymouth Sp. Fury	118	7.50/14	V8-3.906 x 3.312	318	VO	9.0	260@4400	.818	5	.010H	.018H
Pontiac 59-21	122	8.00/14	V8-3.062 x 3.75	389	VO	8.6	245@4200	.630	5	hy	hy
Pontiac 59-24	124	8.00/14	V8-3.062 x 3.75	389	VO	8.6	245@4200	.630	5	hy	hy
Pontiac 59-27, 28	122	8.00/14	V8-3.062 x 3.75	389	VO	8.6	260@4200	.668	5	hy	hy
Rambler Six	100	5.90/15	6-3.125 x 4.25	195.6	IL	8.0	90@3800	.460	4	.016C	.018C
Rambler Amer.	108	6.40/15	6-3.125 x 4.25	195.6	IO	8.7	127@4200	.649	4	.012H	.016H
Rambler Rebel	108	7.50/14	V8-3.50 x 3.25	250	VO	8.7	215@4900	.860	5	.012H	.014H
Rambler Amb.	117	8.00/14	V8-4.00 x 3.25	327	VO	9.7	270@4700	.826	5	hy	hy
Studebaker Lark VI	108 1/2	5.90/15	6-3.00 x 4.00	170	IL	8.3	90@4000	.531	4	.018C	.018C
Studebaker Lark VIII	108 1/2	6.40/15	V8-3.562 x 3.25	259	VO	8.8	180@4500	.694	5	.026C	.026C
Studebaker S.H. 6	120 1/2	6.40/15	6-3.00 x 4.00	170	IL	8.3	90@4000	.531	4	.018C	.018C
Studebaker S.H. V8	120 1/2	6.70/15	V8-3.562 x 3.25	259	VO	8.8	180@4500	.694	5	.026C	.026C
Willys Jeep CJ-5, CJ-3B	80	6.40/15	4-3.125 x 4.375	134	FH	6.9	72@4000	.538	3	.018C	M
Willys Jeep CJ-6	101	7.00/15	4-3.125 x 4.375	134	FH	6.9	72@4000	.538	3	.018C	M
Willys Station Wagon	104	7.00/15	6-3.3125 x4.375	226	IL	7.3	115@3650	.508	4	.014C	.014C
Willys Jeep DJ3A	80	6.40/15	4-3.3125 x4.375	134	IL	6.48	60@4000	.447	3	.016C	.016C
Willys Sta. Wagon 6-85	104	7.00/15	6-3.125 x 3.50	161	FH	6.90	75@4000	.466	4	.018C	.016C

ABBREVIATIONS:

AC - AC Spark Plug
AO - Automatic optional
AL - Auto Lite
a - others also
b - left side 3/8, right side 0.
B - Before top dead center
C - Carter carburetor
CB - Carter Ball and Ball type
CE - Cross elliptic spring
CH - Champion Spark Plug
CS - Coil Spring
DR - Delco Remy
EX - Exposed propeller shaft
Exr - Exposed on rear drive models
f - Applies to engine with automatic transmission. On manual shift transmission, intake valve opens 25 deg. BTDC.
FO - Ford
FH - Intake valves in head and exhaust valves in block
g - at 5 deg. camber
h - applies to manual steering
H - with engine at operating temperature
HO - Holley
Hy - Hydramatic transmission
hy - Hydraulic tappets
IC - Inclosed propeller shaft
IL - In-line engine with L-head
IO - In-line engine with overhead valves
k - Applies to left side. Right side is zero
m - Eaton free spring is .012 in. Thompson

Tuneup Specifications

Intake Tappet Clearance for Valve Timing	Intake Valve Opens Degrees	Carburetor Make	Make of Ignition System	Breaker Point Gap	Breaker Points Open - Deg.	SPARK PLUGS			Auto. Trans. Type	Propeller Shaft	Front Suspension	Rear Suspension	WHEEL ALIGNMENT			King Pin Inclination	Cooling System Capacity, Qts. Without Heater	Crankcase Capacity, Qts.
						Make	Model	Gap					Caster	Camber	Toe-In			
hy	35f	S	DR	.015	4B	AC	44S	.032	TQ	IC	CS	CS	-1 1/2	+ 1/2	3/32	7 g	16 1/2	4
hy	33	C	DR	.015	4B	AC	44S	.032	TQ	IC	CS	CS	-1 1/2	+ 1/2	3/32	7 g	16 1/2	4
hy	33	C	DR	.015	4B	AC	44S	.032	TQ	IC	CS	CS	-1 1/2	+ 1/2	3/32	7 g	16 1/2	4
hy	27	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	CS	- 1/2	0	3/16	4	18 1/2	5
hy	27	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	CS	-1/2	0	3/16	4	18 1/2	5
hy	27	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	CS	-1 1/4	0	3/16	4	18 1/2	5
hy	27	C,R	DR	.016	5B	AC	44	.035	Hy	Ex	CS	CS	- 1/2	0	3/16	4	18 1/2	5
hy	16	R	DR	.016	5B	AC	44	.035	TQ	Ex	CS	CS	0	+ 1/2	1/16	7 1/6	17	5
hy	12 1/2	R	DR	.019	4B	AC	44	.035	TQ	Ex	CS	CS	0	+ 1/2	1/16	7 1/6	17 1/2	4
hy	18 1/2	R	DR	.019	4B	AC	44N	.035	TQ	Ex	CS	CS	0	+ 1/2	1/16	7 1/6	21	4
hy	12 1/2	C	DR	.018	4B	AC	46	.035	TQ	Ex	CS	Se	+ 2	0	1/16	4	17 1/2	4
hy	12 1/2	C	DR	.018	4B	AC	46	.035	TQ	Ex	CS	Se	+ 2	0	1/16	4	17 1/2	4
hy	12 1/2	C	DR	.018	4B	AC	46	.035	TQ	Ex	CS	Se	+ 2	0	1/16	4	17 1/2	4
hy	22	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	17	5
hy	22	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	22	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	20	C	AL	.017	10B	AL	A32	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	22	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	15	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	15	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	15	5
hy	15	C	AL	.017	10B	AL	A42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	15	5
hy	20	C	AL	.017	10B	AL	A32	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	15	5
.011	12	C	AL	.020	2 1/2B	AL	AR51	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	13	5
hy	14	C	AL	.017	10B	AL	AR42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	20	5
hy	15	C	AL	.017	10B	AL	AR42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	15	C	AL	.017	10B	AL	AR42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	20	C	AL	.017	10B	AL	A32	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
hy	20	C	AL	.017	10B	AL	A32	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	16	5
.019C	17	HO	HO	.025	4B	CH	870	.034	TQ	Ex	CS	Se	+ 1 1/2	+ 7/8	1/16	6 3/4	15	4
.019C	18	FO,HO	FO,HO	.015	3B	CH	F14Y	.034	TQ	Ex	CS	Se	+ 1 1/2	+ 7/8	1/16	6 3/4	19	5
hy	22	FO,HO	FO,HO	.015	3B	CH	F11Y	.034	TQ	Ex	CS	Se	+ 1 1/2	+ 7/8	1/16	6 3/4	19	5
hy	22	FO,HO	FO,HO	.015	3B	CH	F11Y	.034	TQ	Ex	CS	Se	+ 1 1/2	+ 7/8	1/16	6 3/4	19	5
.019C	17	HO	HO	.025	4B	CH	870	.034	TQ	Ex	CS	Se	+ 1/2	+ 1	1/16	6 3/4	15	4
.018C	12	FO,HO	FO,HO	.015	3B	CH	F14Y	.034	TQ	Ex	CS	Se	+ 1/2	+ 1	1/16	6 3/4	19	5
hy	22	FO,HO	FO,HO	.015	3B	CH	F11Y	.034	TQ	Ex	CS	Se	+ 1/2	+ 1	1/16	6 3/4	19	5
hy	22	FO,HO	FO,HO	.015	3B	CH	F11Y	.034	TQ	Ex	CS	Se	+ 1/2	+ 1	1/16	6 3/4	19	5
hy	22	FO,HO	FO,HO	.015	3B	CH	F11Y	.034	TQ	Ex	CS	Se	+ 1	+ 1	1/16	7°7"	19	5
hy	27	C	FO	.015	7B	CH	F11Y	.034	TQ	Ex	CS	Se	+ 1	+ 1	1/16	7°7"	20	5
hy	22	C	FO	.015	6B	CH	F11Y	.034	TQ	Ex	CS	Se	- 3/4	+ 3/8	1/8	7°26"n	23	5
.019	18	HO	FO	.015	6B	CH	F14Y	.034	TQ	Ex	CS	Se	- 3/4	+ 3/8	1/8	7 n	21	5
hy	22	FO	FO	.015	6B	CH	F11Y	.034	TQ	Ex	CS	Se	- 3/4	+ 3/8	1/8	7 n	21	5
hy	22	C	FO	.015	6B	CH	F11Y	.034	TQ	Ex	CS	Se	- 3/4	+ 3/8	1/8	7 n	21	5
hy	16	R	DR	.016	5B	AC	44	.030	Hy	Ex	CS	Se	+ 1/2	+ 1/8	1/32	10	20	4
hy	16	R	DR	.016	5B	AC	44	.030	Hy	Ex	CS	Se	+ 1/2	+ 1/8	1/32	10	20	4
hy	16	R	DR	.016	5B	AC	44	.030	Hy	Ex	CS	Se	+ 1/2	+ 1/8	1/32	10	20	4
.010	12	C	AL	.020	2 1/2B	AL	AR51	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	13	5
.010	17	C	AL	.017	10B	AL	AR42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	20	5
.010	17	C	AL	.017	10B	AL	AR42	.035	TQ	Ex	TB	Se	- 3/4 h	+ 3/8 K	1/8	6 1/2	20	5
hy	22	R	DR	.016	6B	AC	45	.035	Hy	Ex	CS	CS	- 1 1/2	+ 1/4	1/32	4 1/2	21.4	5
hy	22	R	DR	.016	6B	AC	45	.035	Hy	Ex	CS	CS	- 1 1/2	+ 1/4	1/32	4 1/2	21.4	5
hy	22	C	DR	.016	6B	AC	45	.035	Hy	Ex	CS	CS	- 1 1/2	+ 1/4	1/32	4 1/2	21.4	5
.016	10	C	DR	.016	3B	CH	H10	.035	TQ	Ex	CS	Se	0	+ 1/4	1/8	6°11"	11	4
.012	12 1/2	HO	DR	.016	5B	AL	AL7	.035	TQ	IC	CS	CS	+ 1/2 h	0	1/8	6°11"	10	4
.012	12 1/2	HO	DR	.016	5B	AL	AL7	.035	TQ	IC	CS	CS	+ 1/2 h	0	1/8	6°11"	20	4
hy	12 1/2	HO	DR	.016	5B	AL	AL7	.035	TQ	IC	CS	CS	+ 1/2 h	0	1/8	6°11"	19	4
.018	15	C	AL	.020	0	CH	J7	.030	TQ	Ex	CS	Se	- 1 3/4	+ 1/2	1/16	6	11	5
.026	11	S	DR	.016	0	CH	H18Y	.035	TQ	Ex	CS	Se	- 1 3/4	+ 1/2	1/16	6	17	5
.018	15	C	AL	.020	0	CH	J7	.030	TQ	Ex	CS	Se	- 1 3/4	+ 1/2	1/16	6	11	5
.026	11	S	DR	.016	0	CH	H18Y	.035	TQ	Ex	CS	Se	- 1 3/4	+ 1/2	1/16	6	17	5
.018	9	C	AL	.020	5B	CH	J7	.030	N	Exr	Ser	Se	+ 3	+ 1 1/2	1/16	7 1/2	11	4
.018	9	C	AL	.020	5B	CH	J7	.030	N	Exr	Ser	Se	+ 3	+ 1 1/2	1/16	7 1/2	11	4
.014	10	C	AL	.020	4B	CH	J7	.030	TQ	CE	Ser	Se	+ 1	+ 1	3/32	5	13	5
.016C	9	C	AL	.020	5B	CH	J7	.030	N	Exr	Ser	Se	+ 3	+ 1	1/16	7 1/2	11	4
.018	9	C	AL	.020	5B	CH	J7	.030	TQ	Exr	Ser	Se	+ 1	+ 1	3/32	5	11	5

	Roto-valve .016 in.
n	- at 3/4 deg. camber
O	- Optional
N	- None available
R	- Rochester carburetor
S	- Stromberg carburetor
Ser	- Semi-elliptic springs with solid axle on rear drive models
Se	- Semi-elliptic springs
TB	- Torsion bar
TC	- Top center
TQ	- Torque converter
TT	- Torque tube
Tr	- Transverse springs
VO	- V-engine with overhead valves

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MAKE AND MODEL	Wheelbase	Tire Size	No. of Cylinder Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Ratio	Maximum Brake Horse Power	H.P. per Cu. In.	No. of Main Bearings	Operating Tappet Clearance Intake	Operating Tappet Clearance Exhaust	Intake Tappet Clearance for Valve Timing
Buick LeSabre	123	7.60/15	V8-4.125x3.4	364	VO	10.25	250@4400	.696	5	hy	hy	hy
Buick Invicta	123	7.60/15	V8-4.1875x3.64	401	VO	10.25	325@4400	.810	5	hy	hy	hy
Buick Electra	126.3	8.00/15	V8-4.1875x3.64	401	VO	10.25	325@4400	.810	5	hy	hy	hy
Cadillac 60, 62, 63	130	8.00/15	V8-4.00x3.875	390	VO	10.5	325@4800	.833	5	hy	hy	hy
Cadillac 64	130	8.00/15	V8-4.00x3.875	390	VO	10.5	345@4800	.885	5	hy	hy	hy
Cadillac 67	149.8	8.20/15	V8-4.00x3.875	390	VO	10.5	325@4800	.833	5	hy	hy	hy
Chevrolet Six	119	7.50/14	6-3.56x3.94	235.5	IO	8.25	135@4000	.575	4	hy	hy	hy
Chevrolet 283	119	7.50/14	V8-3.875x3.00	283	VO	8.50	170@4200	.600	5	hy	hy	hy
Chevrolet 348	119	7.50/14	V8-4.125x3.25	348	VO	9.50	250@4400	.560	5	hy	hy	hy
Chevrolet Corvette	102	6.70/15	V8-3.875x3.00	283	VO	9.50	230@4800	.815	5	.012H	.018H	.012
Chevrolet Corvair	108	6.50/13	6-3.375x2.60	140	FA	8.00	80@4400	.571	4	hy	hy	hy
Chrysler Wind.	122	8.00/14	V8-4.03x3.75	383	VO	10.0	305@4600	.795	5	hy	hy	hy
Chrysler Sara	122	8.50/14	V8-4.03x3.75	383	VO	10.0	325@4600	.850	5	hy	hy	hy
Chrysler N. Y.	126	9.00/14	V8-4.18x3.75	413	VO	10.0	350@4600	.850	5	hy	hy	hy
Comet	114	6.00/13	6-3.50 x 2.50	144.3	VO	8.7	90@4200	.625	4	.016H	.016H	.016
DeSoto PS1-L	122	8.00/14	V8-4.12x3.38	361	VO	10.0	295@4600	.818	5	hy	hy	hy
DeSoto PS3-M	122	8.00/14	V8-4.25x3.38	383	VO	10.0	305@4600	.795	5	hy	hy	hy
Dodge Matador	122	8.00/14	V8-4.12x3.38	361	VO	10.0	295@4600	.818	5	hy	hy	hy
Dodge Polara	122	8.00/14	V8-4.25x3.38	383	VO	10.0	325@4600	.849	5	hy	hy	hy
Dodge Dart PD3	118a	7.50/14	6-3.40x4.125	225	IO	8.5	145@4000	.645	4	.010H	.020H	.010
Dodge Dart PD4	118a	7.50/14	V8-3.91x3.31	318	VO	9.0	230@4400	.724	5	.010H	.018H	.010
Dodge Dart PD4-H	118	7.50/14	V8-4.12x3.38	361	VO	10.0	310@4800	.859	5	hy	hy	hy
Edsel Six	120	7.50/14	6-3.625x3.60	223	VO	8.4	145@4000	.650	4	.019H	.019H	.019H
Edsel 2V Eight	120	7.50/14	V8-3.75x3.30	292	VO	8.8	185@4200	.635	5	.019H	.019H	.019H
Edsel 4V Eight	120	8.00/14	V8-4.00x3.50	352	VO	9.6	300@4000	.851	5	hy	hy	hy
Falcon	109.5	6.00/13	6-3.50x2.50	144.3	IO	8.7	90@4200	.623	4	.016H	.016H	.016
Ford Six	119	7.50/14	6-3.62x3.60	223	VO	8.4	145@4000	.650	4	.019H	.019H	.019
Ford 292	119	7.50/14	V8-3.75x3.30	292	VO	8.8	185@4200	.635	5	.019H	.018H	.019
Ford 352	119	8.00/14	V8-4.00x3.50	352	VO	8.9	235@4400	.667	5	hy	hy	hy
Ford 430	119	8.00/14	V8-4.30x3.70	430	VO	10.0	350@4600	.814	5	hy	hy	hy
Ford Thunderbird 352	113	8.00/14	V8-4.00x3.50	352	VO	9.6	300@4600	.852	6	hy	hy	hy
Ford Thunderbird 430	113	8.50/14	V8-4.30x3.70	430	VO	10.0	350@4600	.814	5	hy	hy	hy
Lincoln & Continental	131	9.50/14	V8-4.30x3.70	430	VO	10.0	315@4100	.725	5	hy	hy	hy
Mercury Mtrey.	126	8.00/14	V8-3.80x3.44	312	VO	8.9	205@4000	.857	5	.019H	.019H	.019
Mercury Mtclar.	126	8.50/14	V8-4.30x3.70	430	VO	10.0	310@4100	.721	5	hy	hy	hy
Mercury P. Lane	126	8.50/14	V8-4.30x3.70	430	VO	10.0	310@4100	.721	5	hy	hy	hy
Oldsmobile Dyn. 88	123	8.50/14	V8-4x3.688	371	VO	8.75	240@4400	.648	5	hy	hy	hy
Oldsmobile Sup. 88	123	8.50/14	V8-4.125x3.688	394	VO	9.75	315@4600	.799	5	hy	hy	hy
Oldsmobile 98	126.3	9.00/14	V8-4.125x3.688	394	VO	9.75	315@4600	.799	5	hy	hy	hy
Plymouth Six	118	7.50/14	6-3.40x4.125	225	IO	8.50	145@4000	.645	4	.013c	.023c	.013
Plymouth Fury 318	118	7.50/14	V8-3.90x3.31	318	VO	9.0	230@4400	.724	5	.010H	.018H	.010
Plymouth 361	118	7.50/14	V8-4.12x3.38	361	VO	10.0	295@4600	.818	5	hy	hy	hy
Pontiac-Cata. Vent.	122	8.00/14	V8-4.06x3.75	389	VO	8.61	215@3600	.554	5	hy	hy	hy
Pontiac-S. Chief,Bonn.	124	8.00/14	V8-4.06x3.75	389	VO	8.61	281@4400	.722	5	hy	hy	hy
Pontiac Temp. 425A	124	8.00/14	V8-4.06x3.75	389	VO	10.75	348@ N	.895	5	hy	hy	hy
Rambler Amer.	100	5.90/15	6-3.125x4.25	195.6	IL	8.0	90@3800	.461	4	.016	.018	.016
Rambler 6010	108	6.40/15	6-3.125x4.25	195.6	IO	8.7	127@4200	.650	4	.012H	.016H	.012
Rambler 6020	108	7.50/14	V8-3.50x3.25	250.0	VO	8.7	200@4900	.800	5	.012H	.014H	.012
Rambler 6080	117	8.00/14	V8-4.0x3.25	327.0	VO	8.7	250@4700	.765	5	hy	hy	hy
Studebaker Lark VI	108.5a	5.90/15	6-3.0x4.0	169.6	IL	8.3	90@4000	.532	4	.018c	.018c	.018c
Studebaker Lark VIII	113a	6.40/15	V8-3.562x3.25	259.2	VO	8.8	180@4500	.695	5	.026c	.026c	.026c
Studebaker Hawk	120.5	6.70/15	V8-3.562x3.625	289	VO	8.8	210@4500	.726	5	.026c	.026c	.026c
Valiant	106.5	6.50/13	6-3.40x3.125	170	IO	8.5	N	N	4	.010H	.020H	.010

ABBREVIATIONS:

AC - AC Spark Plug
AL - AutoLite
AO - Automatic Optional
a - Others also
air - Air cooled engine
b - left side 3/8, right side 0
B - Before topdead center
c - with engine cold
C - Carter carburetor
CH - Champion Spark Plug
CS - Coil Spring
DR - Delco Remy
EX - Exposed propeller shaft
f - Applies to engine with automatic transmission. On manual shift transmissions, intake valve opens 25 deg.BTDC
FA - Horizontal opposed
FI - Fuel injection
FO - Ford
g - At 5 deg. camber
h - Applies to manual steering
H - With engine at operating temperature
HO - Holley
Hy - Hydramatic transmission
IC - Enclosed propeller shaft
IO - In-line engine with overhead valves
IL - In-line engine with valves in block. (L-head)
k - Applies to left side. Right side is zero
N - None available
n - At 3/4 deg. camber
O - Optional
p - With two barrel carburetor

Tuneup Specifications

Intake Valve Opens Deg. B.T.D.C.	Carburetor Make	Ignition System Make	Breaker Point Gap	Breaker Point Open Deg. B.T.D.C.	Spark Plugs			Auto. Transmission Type	Propeller Shaft	Front Suspension	Rear Suspension	Wheel Alignment				Cooling System Capacity Without Heater	Crankcase Capacity Qts.
					Make	Model	Gap					Caster	Camber	Toe-In	King Pin Inclination		
35j	C,S	DR	.015	5B	AC	44S	.032	TQ	TT	CS	CS	-2	+1/2	5/32	7	18.5	4
33	C,R	DR	.015	12B	AC	44S	.032	TQ	TT	CS	CS	-2	+1/2	5/32	7	18.5	4
33	C,R	DR	.015	12B	AC	44S	.032	TQ	TT	CS	CS	-2	+1/2	5/32	7	18.5	4
39	C,R	DR	.016	5B	AC	44	.035	Hy	EX	CS	CS	-1	0	1/4	4	19.25	5
39	C,R	DR	.016	5B	AC	44	.035	Hy	EX	CS	CS	-1	0	1/4	4	19.25	5
39	C,R	DR	.016	5B	AC	44	.035	Hy	EX	CS	CS	-1	0	1/4	4	19.25	5
16	R	DR	.019	5B	AC	44	.035	TQ	EX	CS	CS	0	+1/2	1/16	7°11"	18	5
18p	R,C	DR	.019	4B	AC	44	.035	TQ	EX	CS	CS	0	+1/2	1/16	7°11"	18 1/2	4
18 1/2	R,C	DR	.019	8q	AC	44N	.035	TQ	EX	CS	CS	0	+1/2	1/16	7°11"	22	4
12 1/2a	C,FI	DR	.019	4B	AC	44	.035	TQ	EX	CS	Se	+2	0	0	4	16 1/2	5
15	R	DR	.019	4B	AC	44FF	.035	TQ	RR	CS	CS	+4	+1/2	1/8	7	Air	4
15	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
15	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
15	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
15	HO	FO	.025	TC	CH	F14Y	.034	TQ	EX	CS	Se	+1 1/2	+3/4	1/16	7	9.3	4.5
15	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-1/2h	+3/8t	1/8	6 1/2	17	5
15	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-1/2h	+3/8t	1/8	6 1/2	17	5
15	S	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
15	HO	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
TC	C	AL	.020	2 1/2B	AL	AG42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	14	4
17	C	AL	.016	5B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	21	5
20	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
17	HO	HO	.025	4B	C	870	.034	TQ	EX	CS	Se	0	+1	1/8	6 3/4	16	4
12	HO,FO	HO	.015	3B	C	F14Y	.034	TQ	EX	CS	Se	0	+1	1/8	6 3/4	20	5
26	HO,FO	HO	.015	6B	C	F14Y	.034	TQ	EX	CS	Se	0	+1	1/8	6 3/4	20	5
15	HO	FO	.025	22Bv	CH	F14Y	.034	TQ	FX	CS	Se	+1 1/2	45'	3/32	7n	9.3	3 1/2
17	HO	HO	.025	4Bv	C	870	.034	TQ	EX	CS	Se	0	1	1/8	6 3/4	15	4
12	HO,FO	HO	.015	3Bv	C	F14Y	.034	TQ	EX	CS	Se	0	1	1/8	6 3/4	19	5
22	HO,FO	HO	.015	3Bv	C	F11Y	.034	TQ	EX	CS	Se	0	1	1/8	6 3/4	19	5
27	HO,FO	HO	.015	6Bv	C	F11Y	.034	TQ	EX	CS	Se	0	1	1/8	6 3/4	20	5
22	HO,FO	HO	.015	3Bv	C	F11Y	.034	TQ	EX	CS	Se	1	1	1/8	7°7'	20	5
27	HO,FO	HO	.015	6Bv	C	F11Y	.034	TQ	EX	CS	Se	1	1	1/8	7°7'	20	5
22	C	FO	.015	6B	C	F11Y	.034	TQ	EX	CS	Se	+3/4	+3/8	1/8	7°26"	26	5
12	HO	FO	.015	3B	C	F14Y	.034	TQ	EX	CS	Se	-3/4	+3/8	1/8	7	21	5
22	C	FO	.015	6B	C	F11Y	.034	TQ	EX	CS	Se	-3/4	+3/8	1/8	7	22	5
22	C	FO	.015	6B	C	F11Y	.034	TQ	EX	CS	Se	-3/4	+3/8	1/8	7	22	5
14	R	DR	.016	5B	AC	45	.030	Hy	EX	CS	Se	-1/2	-1/2	1/16	10	21	4
16	R	DR	.016	5B	AC	44	.030	Hy	EX	CS	Se	-1/2	-1/2	1/16	10	21	4
16	R	DR	.016	5B	AC	44	.030	Hy	EX	CS	Se	-1/2	-1/2	1/16	10	21	4
0	C	AL	.020	2 1/2B	AL	AG42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	15	4
17	C	AL	.016	5B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	21	5
15	C	AL	.016	10B	AL	A42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	6 1/2	17	5
14	R	DR	.016	6B	AC	45S	.035	Hy	EX	CS	CS	-1 1/2	+1/4	1/16	4 1/2	22.2	5
14	C	DR	.016	6B	AC	45S	.035	Hy	EX	CS	CS	-1 1/2	+1/4	1/16	4 1/2	22.2	5
14	C	DR	.016	6B	AC	45S	.035	Hy	EX	CS	CS	-1 1/2	+1/4	1/16	4 1/2	22.2	5
10	C	AL	.019	3B	AL	AL-7	.035	TQ	EX	CS	Se	+1/2	0	3/32	8 1/2	12	4
12 1/2	HO	DR	.016	5B	C	H10	.035	TQ	TT	CS	CS	+1/2	0	5/32	6°41	11	4
12 1/2	HO	AL	.016	TC	C	H10	.035	TQ	TT	CS	CS	+1/2	0	3/16	6°41	21	4
12 1/2	HO	AL	.016	TC	C	H10	.035	TQ	TT	CS	CS	+1/2	0	3/16	6°41	20	4
15	C	AL	.020	2B	C	J-7	.030	TQ	EX	CS	Se	-1 3/4	+1/2	1/16	6	12	5
11	S	DR	.016	4B	C	H18Y	.035	TQ	EX	CS	Se	-1 3/4	+1/2	1/16	6	18	5
11	S	DR	.016	4B	C	H18Y	.035	TQ	EX	CS	Se	-1 3/4	+1/2	1/16	6	18	5
8	C	AL	.019	5B	AL	AG42	.035	TQ	EX	TB	Se	-3/4h	+3/8t	1/8	7 1/2	14	4

q - With regular cam
R - Rochester carburetor
RR - Rear engine rear drive
S - Stromberg carburetor
Se - Semi-elliptic springs
TB - Torsion bar
TC - Top center
TQ - Torque converter
TT - Torque tube
t - Applies to left side, right side 1/8 deg.
VO - V- engine with overhead valves
v - Applies to manual shift transmission

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MAKE AND MODEL	Wheelbase	No. of Cylinders Bore & Stroke	Displacement	Valves and Cylinder Arrangement	Compression Pressure	Maximum Brake Horsepower	Valve Tappet Clearance		Cylinder Bolt Torque	Connecting Rod Bolt Torque	Main Bearing Bolt Torque
							Intake	Exhaust			
Buick LaSabre	123	V8-4.125x3.40	364	VO	180	250@4400	hy	hy	70	42	105
Buick Invicta	123	V8-4.1875x3.64	401	VO	180	325@4400	hy	hy	70	42	105
Buick Electra	126	V8-4.1875x3.64	401	VO	180	325@4400	hy	hy	70	42	105
Buick Special	112	V8-3.50x2.80	215	VO	155	155@4400	hy	hy	52	32	55
Cadillac 62,60	129-1/2	V8-4.00x3.875	390	VO	175	325@4800	hy	hy	67	42	95
Cadillac 75	150	V8-4.00x3.875	390	VO	175	325@4800	hy	hy	67	42	95
Chevrolet Six	119	6-3.562x3.94	235	IO	130	135@4000	.008H	.015H	92	40	105
Chevrolet 283	119	V8-3.875x3.00	283	VO	140	170@4200	hy	hy	65	32	65
Chevrolet 348	119	V8-4.125x3.25	348	VO	150	250@4400	hy	hy	65	40	100
Chrysler Newpt.	122	V8-4.125x3.375	361	VO	150	265@4400	hy	hy	70	45	85
Chrysler Wind.	122	V8-4.25x3.375	383	VO	165	305@4600	hy	hy	70	45	85
Chrysler N.Y.	126	V8-4.1875x3.75	413	VO	165	350@4600	hy	hy	70	45	85
Comet 144	114	6-3.500x2.50	144	IO	170	90@4200	.016H	.016H	70	22	70
Comet 170	114	6-3.500x2.9375	170	IO	170	101@4200	.016H	.016H	70	22	70
Corvair	108	6-3.4375x2.60	145	HA	130	80@4400	hy	hy	30	23	---
Corvair Monza	108	6-3.4375x2.60	145	HA	130	98@4600	hy	hy	30	23	---
Corvette	102	V8-3.875x3.00	283	VO	150	230@4800	hy	hy	65	32	65
Desoto	122	V8-4.125x3.375	361	VO	150	265@4400	hy	hy	70	45	85
Dart Six	119	6-3.4062x4.125	225	IO	120	145@4000	.010H	.020H	65	45	85
Dart V8	118	V8-3.9062x3.312	318	VO	125	230@4400	.010H	.018H	85	45	85
Dodge V8 36	122	V8-4.125x3.375	361	VO	160	265@4400	hy	hy	70	45	85
Dodge V8 383	122	V8-4.250x3.375	383	VO	160	325@4600	hy	hy	70	45	85
Dodge Ram J.	122	V8-4.250x3.375	383	VO	160	330@4800	hy	hy	70	45	85
Falcon 144	109-1/2	6-3.50x2.50	144	IO	170	90@4200	.016H	.016H	70	22	70
Falcon 170	109-1/2	6-3.9062x3.312	170	IO	170	101@4200	.016H	.016H	70	22	70
Ford Six	119	6-3.625x3.60	223	IO	150	135@4000	.019H	.019H	110	42	100
Ford V8 292	119	V8-3.75x3.30	292	VO	160	175@4200	.019H	.019H	70	42	85
Ford V8 352	119	V8-4.00x3.50	352	VO	180	220@4400	hy	hy	85	42	100
Ford V8 390	119	V8-4.0468x3.781	390	VO	180	300@4600	hy	hy	85	42	100
Lancer	106-1/2	6-3.406x3.125	170	IO	130	101@4400	.010H	.020H	65	45	85
Lark Six	108-1/2	6-3.00x4.00	170	IO	140	112@4500	.026C	.026C	48	30	92
Lark Eight	108-1/2	V8-3.56x3.25	259	VO	140	180@4500	.026C	.026C	60	53	90
Lincoln	123	V8-4.30x3.70	430	VO	160	315@4100	hy	hy	95	47	100
Mercury Six	120	6-3.625x3.60	223	IO	150	135@4000	.019C	.019C	115	42	100
Mercury 292	120	V8-3.75x3.30	292	VO	160	175@4200	.019C	.019C	70	42	85
Mercury 352	120	V8-4.00x3.50	352	VO	180	220@4400	hy	hy	85	42	100
Mercury 390	120	V8-4.05x3.784	390	VO	180	300@4600	hy	hy	85	42	100
Oldsmobile 88	123	V8-4.125x3.688	394	VO	150	250@4200	hy	hy	70	45	120
Oldsmobile 98	126	V8-4.125x3.688	394	VO	160	325@4600	hy	hy	70	45	120
Plymouth Six	118	6-3.40x4.125	225	VO	145	145@4000	.010H	.020H	65	45	85
Plymouth STD8	118	V8-3.906x3.312	318	VO	150	230@4400	.010H	.020H	85	45	85
Plymouth G.C.	118	V8-4.125x3.375	361	VO	150	305@4800	hy	hy	70	45	85
Plymouth S.C.	118	V8-4.25x3.375	383	VO	165	330@4800	hy	hy	70	45	85
Pontiac Cat.,Vent.	119	V8-4.0625x3.75	389	VO	145	215@3600	hy	hy	95	45	95
Pontiac Bon., S.C.	123	V8-4.0625x3.75	389	VO	145	235@3600	hy	hy	95	45	95
Pontiac Tempest	112	4-4.0625x3.75	194.5	IO	140	110@3800	hy	hy	95	45	95
Pontiac Tempest	112	4-4.0625x3.75	194.5	IO	140	140@4400	hy	hy	95	45	95
Pontiac Tempest	112	V8-3.50x2.80	215.0	VO	140	155@4600	hy	hy	52	32	52
Rambler Amer.Del	100	6-3.125x4.25	196	IL	130	90@3800	.016C	.018C	60	30	65
Rambler Amer.Cust	100	6-3.125x4.25	196	IO	130	125@4200	.012H	.016H	60	30	65
Rambler Cl. Six	108	6-3.125x4.25	196	IO	130	127@4200	.012H	.016H	65	30	70
Rambler Cl. 8	108	V8-3.50x3.25	250	VO	130	200@4900	.014H	.016H	65	50	---
Rambler Amb.	117	V8-4.00x3.25	327	VO	150	250@4700	hy	hy	---	--	---
Studebaker Hawk	120-1/2	V8-3.563x3.625	289	VO	140	210@4500	.026C	.026C	60	53	90

Abbreviations:

hy - Hydraulic valve lifters
VD - Vibration damper
VO - Vee type engine with overhead valves
L - Left
H - Hot
IO - In line engine with overhead valves
f - Flywheel

AL - Auto Lite
M - Manual steering
HA - Horizontal opposed
P - Front pulley
CH - Champion Spark Plug
C - Cold
IL - In line L head

Tuneup Specifications

Firing Order	Timing Mark Location	Breaker Point Opens BTDC	Breaker Point Gap	Cam Angle	Spark Plug			Caster	Camber	Toe-In	Steering Axis Inclination	Cooling System Capacity	Crankcase Capacity Qts.
					Make	Model	Gap						
12784563	VD	12	.015	30	AC	44S	.032	-1	+3/8	3/16	10	18-1/2	4
12784563	VD	12	.015	30	AC	44S	.032	-1	+3/8	3/16	10	18-1/2	4
12784563	VD	12	.015	30	AC	44S	.032	-1	+3/8	3/16	10	18-1/2	4
18436572	VD	5	.016	30	AC	45FFS	.035	-2	-5/8	1/16	7-1/2	13-1/2	4
18436572	VD	5	.016	30	AC	44	.035	-7/8	L+1/8	3/16	6	19-1/4	5
18436572	VD	5	.016	30	AC	44	.035	-7/8	R-1/8	3/16	6	20-3/4	5
153624	f	5	.016	32	AC	44	.035	0	+1/2	1/16	7-1/6	18	5
18436572	VD	4	.016	30	AC	44	.035	0	+1/2	1/16	7-1/6	18-1/2	4
18436572	VD	8	.019	30	AC	44N	.035	0	+1/2	1/16	7-1/6	22	4
18436572	VD	10	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	17	5
18436572	VD	10	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	17	5
18436572	VD	10	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	17	5
153624	P	2	.025	36.5	CH	F14Y	.034	+1/2	+1/2	1/4	7	9.7	3-1/2
153624	P	2	.025	36.5	CH	F14Y	.034	+1/2	+1/2	1/4	7	9.7	3-1/2
145236	P	--	.016	33	AC	46FF	.035	+2-3/4	+1/2	1/8	7	AIR	4
145236	P	--	.016	33	AC	46FF	.035	+2-3/4	+1/2	1/8	7	AIR	4
18436572	VD	4	.016	30	AC	44	.035	+2	0	1/16	4	16-1/2	5
18436572	VD	10	.017	30	AL	42	.035	+3/4	+1/2	1/8	6-1/2	17	5
153624	VD	2-1/2	.020	42	AL	AG52	.035	-1/2M	+1/2	1/8	6-1/2	14	4
18436572	P	5	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	21	5
18436572	VD	10	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	17	5
18436572	VD	10	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	17	5
18436572	VD	10	.017	30	AL	A42	.035	-1/2M	+1/2	1/8	6-1/2	17	5
153624	P	2	.025	36.5	CH	F14Y	.034	+1/2	+1/2	1/4	7	9.7	3-1/2
153624	P	2	.025	36.5	CH	F14Y	.034	+1/2	+1/2	1/4	7	9.7	3-1/2
153624	VD	3	.025	36.5	CH	870	.034	0	+3/8	3/16	6-3/4	16	4
15486372	VD	4	.015	27	CH	F14Y	.034	0	+3/8	3/16	6-3/4	20	5
15486372	VD	3	.015	27	CH	F11Y	.034	0	+3/8	3/16	6-3/4	20	5
15486372	VD	3	.015	27	CH	F11Y	.034	0	+3/8	3/16	6-3/4	20	5
153624	P	2-1/2	.020	42	AL	AG52	.035	+3/4	+1/8	1/8	7-1/2	14	4
153624	VD	2	.020	39	CH	H14Y	.035	-1/2	+1/2	1/16	6	12	5
18436572	VD	4	.016	30	CH	H14Y	.035	-1/2	+1/2	1/16	6	18	5
15426378	VD	6	.015	27	CH	F11Y	.035	-3/4	+3/8	1/8	7	25	5
153624	VD	4	.025	36.5	CH	870	.034	0	+5/8	3/16	---	16	4
15486372	VD	3	.015	27	CH	F14Y	.034	0	+5/8	3/16	---	20	5
15426378	VD	3	.015	27	CH	F11Y	.034	0	+5/8	3/16	---	20	5
15426378	VD	3	.015	27	CH	F11Y	.034	0	+5/8	3/16	---	20	5
18736542	VD	5	.016	30	AC	45	.030	-1/2	+1/4	1/16	10	20-1/4	4
18736542	VD	7-1/2	.016	30	AC	44	.030	-1/2	+1/4	1/16	10	20-1/4	4
153624	VD	2-1/2	.020	39	AL	AG52	.035	-1/2M	+1/2	1/8	6	14	4
18436572	VD	5	.017	30	AL	AG42	.035	-1/2M	+1/2	1/8	6	21	5
18436572	VD	10	.017	30	AL	AG32	.035	-1/2M	+1/2	1/8	6	17	5
18436572	VD	7-1/2	.017	30	AL	AG32	.035	-1/2M	+1/2	1/8	6	17	5
18436572	P	6	.016	30	AC	45S	.035	-1-1/2	+1/4	1/16	4-5/6	19-1/2	4
18436572	P	6	.016	30	AC	45S	.035	-1-1/2	+1/4	1/16	4-5/6	19-1/2	4
1342	VD	6	.016	75	AC	45S	.035	-1-2/3	+1/8	1/16	6-5/6	12.5	4
1342	VD	6	.016	75	AC	45S	.035	-1-2/3	+1/8	1/16	6-5/6	12.5	4
18436572	VD	5	.016	30	AC	45FFS	.035	-1-2/3	+1/8	1/16	6-5/6	12.5	4
153624	VD	3	.016	32	CH	H10	.035	+1/2M	0	1/8	8	12	4
153624	VD	8	.016	32	CH	H10	.035	+1/2M	0	1/8	8	11	4
153624	VD	8	.016	32	CH	H10	.035	+1/2M	0	1/8	8	11	4
18436572	VD	0	.016	30	CH	H10	.035	+1/2M	0	1/8	8	20	4
18436572	VD	0	.016	30	CH	H10	.035	+1/2M	0	1/8	8	19	4
18436572	VD	4	.016	30	CH	H14Y	.035	-1/2	+1/2	1/16	6	18	5

Official Mechanical and

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	Wheelbase	No. of Cylinder Bore and Stroke	Displacement	Valve and Cylinder Arrangement	Compression Pressure	Maximum Brake Horsepower	Valve Tappet Clearance		Cylinder Bolt Torque	Connecting Rod Bolt Torque
							Intake	Exhaust		
Buick Spe. 4000	112	6-3.625x3.20	198	VO		135@4600	hy	hy	70	150
Buick Spe. 4100	112	V8-3.50x2.80	215	VO		155@4600	hy	hy	55	150
Buick LaSabre	123	V8-4.1875x3.64	401	VO	180	280@4400	hy	hy	70	42
Buick Invicta	123	V8-4.1875x3.64	401	VO	180	280@4400	hy	hy	70	42
Buick Electra	126	V8-4.1875x3.64	401	VO	180	280@4400	hy	hy	70	42
Cadillac 62	129-1/2	V8-4.00x3.875	390	VO	175	325@4800	hy	hy	75	45
Cadillac 75	149-4/5	V8-4.00x3.875	390	VO	175	325@4800	hy	hy	75	45
Chevrolet Six	119	6-3.56x3.94	235.5	IO	130	135@4000	hy	hy	92	40
Chevrolet V8-283	119	V8-3.875x3.00	283	VO	150	170@4200	hy	hy	65	32
Chevrolet V8-327	119	V8-4.00x3.25	327	VO	160	250@4400	hy	hy	65	40
Chevrolet V8-409	119	V8-4.3125x3.50	409	VO	150	380@5800	.008H	.018H	-	-
Chevy II Four	110	4-3.876x3.25	153	IO	140	90@4000	hy	hy	92	32
Chevy II Six	110	6-3.5635x3.25	194	IO	140	120@4400	hy	hy	92	32
Chevrolet Corvair	108	6-3.4375x2.60	145	HA	130	80@4400	hy	hy	30	26
Chevrolet Corvette	102	V8-4.00x3.25	327	VO	160	250@4400	hy	hy	65	40
Chrysler Newport	122	V8-4.125x3.375	361	VO	150	265@4400	hy	hy	70	45
Chrysler N.Y.	126	V8-4.187x3.750	413	VO	165	340@4600	hy	hy	70	45
Chrysler 300	122	V8-4.25x3.375	383	VO	165	305@4600	hy	hy	70	45
Chrysler 300 H	122	V8-4.1875x3.750	413	VO	165	380@5000	.015H	.024H	70	45
Chrysler Imper.	129	V8-4.1875x3.750	413	VO	165	340@4600	hy	hy	70	45
Dodge Lancer SL1	106-1/2	6-3.40x3.125	170	IO	145	101@4400	.010H	.020H	65	45
Dodge Dart SD1	116	6-3.40x4.125	225	IO	145	145@4000	.010H	.020H	65	45
Dodge Dart SD2	116	V8-3.91x3.31	318	VO	150	230@4400	.010H	.018H	85	45
Dodge Dart SD2P	116	V8-4.12x3.38	361	VO	150	305@4800	hy	hy	70	45
Ford Fairlane	115-1/2	6-3.50x2.94	170	IO	170	101@4400	.016H	.016H	70	21
Ford Fairlane	115-1/2	V8-3.50x2.87	221	VO	150	145@4400	hy	hy	70	21
Ford Falcon	109-1/2	6-3.50x2.50	144	IO	170	85@4200	.016	.016	70	21
Ford Falcon	109-1/2	6-3.50x2.94	170	IO	170	101@4400	.016	.016	70	21
Ford Galaxie 223	119	6-3.62x3.60	223	IO	150	138@4200	hy	hy	70	42
Ford Galaxie 292	119	V8-3.75x3.30	292	VO	162	170@4200	.018H	.018H	70	42
Ford Galaxie 352	119	V8-4.00x3.50	352	VO	180	220@4300	hy	hy	85	42
Ford Galaxie 390	119	V8-4.05x3.78	390	VO	180	300@4600	hy	hy	85	42
Ford Thunderbird	113	V8-4.05x3.78	390	VO	180	300@4600	hy	hy	85	42
Lincoln Cont.	123	V8-4.2969x3.703	430	VO	160	315@4100	hy	hy	95	47
Mercury Meteor 6	116-1/2	6-3.50x2.937	170	IO	170	101@4400	.016	.016	70	21
Mercury Meteor 8	116-1/2	V8-3.50x2.875	221	VO	150	145@4400	hy	hy	70	21
Mercury Comet	114	6-3.50x2.50	144	IO	170	85@4200	.016	.016	70	21
Mercury Six	120	6-3.62x3.60	223	IO	150	138@4200	hy	hy	70	42
Mercury 292	120	V8-3.75x3.30	292	VO	162	170@4200	.018H	.018H	70	42
Mercury 352	120	V8-4.00x3.50	352	VO	180	220@4300	hy	hy	85	42
Mercury 390	120	V8-4.05x3.78	390	VO	180	300@4600	hy	hy	85	42
Oldsmobile F85	112	V8-3.50x2.80	215	VO	160	155@4800	hy	hy	50	32
Oldsmobile Dyn. 88	123	V8-4.13x3.68	394	VO	150	280@4400	hy	hy	70	43
Oldsmobile Sup. 88	123	V8-4.13x3.68	394	VO	155	330@4600	hy	hy	70	43
Oldsmobile 98	126	V8-4.13x3.68	394	VO	155	330@4600	hy	hy	70	43
Oldsmobile Starf.	123	V8-4.13x3.68	394	VO	160	345@4600	hy	hy	70	43
Plymouth Six	116	6-3.40x4.125	225	IO	145	145@4000	.010H	.010H	65	45
Plymouth 318	116	V8-3.91x3.31	318	VO	150	230@4400	.020H	.018H	85	45
Plymouth 361	116	V8-4.12x3.38	361	VO	150	305@4800	.010H	.018H	70	45
Plymouth Vali.	106-1/2	6-3.40x3.125	170	IO	145	101@4400	.010H	.020H	65	45
Pontiac Cat.	120	V8-4.06x3.75	389	VO	145	215@3600	hy	hy	95	45
Pontiac Star-Chief	123	V8-4.06x3.75	389	VO	145	215@3600	hy	hy	95	45
Pontiac Bonn.	123	V8-4.06x3.75	389	VO	145	235@3600	hy	hy	95	45
Pontiac Temp.	112	4-4.06x3.75	195	VO	140	110@3000	hy	hy	95	45
Rambler Del.	100	6-3.125x4.25	195.6	IL	140	90@3800	.016C	.018C	60	28
Rambler Amer.	100	6-3.125x4.25	195.6	IO	130	125@4200	.012H	.012H	60	28
Rambler Class.	108	6-3.125x4.25	195.6	IO	130	127@4200	hy	hy	60	28
Rambler Amb.	108	V8-4.00x3.25	327	VO	150	250@4700	hy	hy	60	28
Studebaker Lark 6	109	6-3.00x4.00	169.6	IL	140	112@4500	.024H	.026H	48	30
Studebaker Lark V8	113	V8-3.56x3.25	259.2	VO	140	180@4500	.024H	.026H	50	30
Studebaker Hawk	120-1/2	V8-3.562x3.63	289	VO	140	210@4500	.024H	.024H	50	53

Abbreviations

CP - Crankshaft Pulley
CC - Timing Case Cover
TC - Top Center
VO - V type engine, overhead valves

IO - In line engine, overhead valves
HA - Horizontal opposed engine
hy - Hydraulic valve lifters
H - Hot
C - Cold
VD - Vibration damper

f - Flywheel
AC - A C Spark Plug Co.
CH - Champion Spark Plug Co.
AL - Auto-Lite Spark Plugs
M - Manual shift transmission

Tuneup Specifications

Main Bearing Bolt Torque	Firing Order	Timing Mark Location	Breaker Point Opens B. T. D. C.	Breaker Point Gap	Cam Angle	Spark Plugs			Caster Man. Steer.	Camber Rt. Wheel	Toe-In	Steering Axis Inclination	Cooling System Capacity	Crankcase Capacity Qt.
						Make	Model	Gap						
55	165432	VD	5	.016	30	AC	44S	.035	-2	-5/8	1/8	7-1/2	12	4
110	18436572	VD	5	.016	30	AC	45FFS	.035	-2	-5/8	1/8	7-1/2	12	4
105	12784563	VD	12	.016	30	AC	44S	.035	-2	+1/3	3/16	9-5/6	18-1/2	4
105	12784563	VD	12	.016	30	AC	44S	.035	-2	+1/3	3/16	9-5/6	18-1/2	4
105	12784563	VD	12	.016	30	AC	44S	.035	-2	+1/3	3/16	9-5/6	18-1/2	4
95	18436572	VD	5	.016	30	AC	44	.035	-1/2	+3/8	3/16	6	19-1/4	4
95	18436572	VD	5	.016	30	AC	44	.035	-1/2	+3/8	3/16	6	20-3/4	4
105	165432	f	5	.016	30	AC	46	.035	0	+1/2	1/8	7-1/4	18	5
65	18436572	VD	4	.016	30	AC	46	.035	0	+1/2	1/8	7-1/4	18-3/4	4
100	18436572	VD	4	.016	30	AC	44	.035	0	+1/2	1/8	7-1/4	18-3/4	4
-	18436572	VD	12	.016	29	AC	43N	.035	0	+1/2	1/8	7-1/4	18-3/4	6
50	1342	VD	4	.016	30	AC	44N	.035	1	+1/2	1/4	-	9	4
50	153624	VD	8	.016	30	AC	44N	.035	1	+1/2	1/4	-	12	5
-	145236	VD	4	.016	33	AC	46FF	.035	2	+1/2	1/4	-	AIR	4
100	18436572	VD	4	.016	30	AC	44	.035	0	0	1/16	3-5/6	16-1/2	5
85	18436572	VD	10	.017	30	CH	J12Y	.035	-1/2M	+1/2	1/8	6-1/2	17	5
85	18436572	VD	10	.017	30	CH	J12Y	.035	-1/2M	+1/2	1/8	6-1/2	17	5
85	18436572	VD	10	.017	30	CH	J12Y	.035	-1/2M	+1/2	1/8	6-1/2	17	5
85	18436572	VD	10	.017	37	CH	J9Y	.035	-1/2M	+1/2	1/8	6-1/2	17	5
85	18436572	VD	10	.017	30	CH	J12Y	.035	-1/2M	+1/2	1/8	6-1/2	17	5
85	153624	VD	2	.020	42	CH	N16Y	.035	-1/2M	+1/2	1/8	7-1/2	12	4
85	153624	VD	2	.020	42	CH	N16Y	.035	-1/2M	+1/2	1/8	7-1/2	13	4
85	18436572	VD	5	.016	30	CH	J12Y	.035	-1/2M	+1/2	1/8	7-1/2	21	4
85	18436572	VD	10	.016	30	CH	J12Y	.035	-1/2M	+1/2	1/8	7-1/2	17	4
65	153624	CP	4	.025	36	AL	BF82	.034	0	+1/2	1/8	-	9-1/2	3-1/2
70	15426378	VD	6	.015	27	AL	BF92	.034	0	+1/2	1/8	-	14-1/2	4
65	153624	CP	6	.025	36	AL	BF82	.034	+1/2	+1/2	1/4	-	9-7/10	3-1/2
65	153624	CP	6	.025	36	AL	BF82	.034	+1/2	+1/2	1/4	-	9-7/10	3-1/2
100	153624	VD	6	.025	36	AL	BTF6	.034	0	+5/8	1/8	-	16	4
85	15486372	VD	5	.015	27	AL	BF82	.034	0	+5/8	1/8	-	20	5
100	15426378	VD	5	.015	27	AL	BF42	.034	0	+5/8	1/8	-	20	5
100	15426378	VD	5	.015	27	AL	BF42	.034	0	+5/8	1/8	-	20	5
100	15426378	VD	8	.015	27	AL	BF42	.034	-3/4	+3/8	1/8	-	20	5
100	15426378	VD	6	.015	27	CH	F11Y	.035	-3/4	+3/8	1/8	7	25	5
65	153624	CP	6	.025	36	AL	BF82	.035	-	-	-	-	9-7/10	3-1/2
70	15426378	VD	6	.015	27	AL	BF82	.035	-	-	-	-	14-1/2	4
65	153624	CP	6	.025	36	AL	BF82	.034	-	-	-	-	9-7/10	3-1/2
100	153624	VD	6	.025	36	AL	BTF6	.034	0	+5/8	1/8	-	16	4
85	15486372	VD	5	.015	27	AL	BF82	.034	0	+5/8	1/8	-	20	5
100	15426378	VD	5	.015	27	AL	BF42	.034	0	+5/8	1/8	-	20	5
100	15426378	VD	5	.015	27	AL	BF42	.034	0	+5/8	1/8	-	20	5
55	18436572	VD	5	.016	30	AC	46FF	.030	-1	+3/8	1/16	7-1/2	13-1/2	4
120	18736542	VD	5	.016	30	AC		.030	-1/2	+1/4	1/16	10	21-1/4	4
120	18736542	VD	5	.016	30	AC	46F	.030	-1/2	+1/4	1/16	10	21-1/4	4
120	18736542	VD	5	.016	30	AC	45	.030	-1/2	+1/4	1/16	10	21-1/4	4
120	18736542	VD	5	.016	30	AC	45	.030	-1/2	+1/4	1/16	10	21-1/4	4
85	153624	CC	2-1/2	.020	42	CH	N16Y	.035	-1/2	+1/2	1/8	7-1/2	13	4
85	18436572	CC	5	.016	30	CH	J12Y	.035	-1/2	+1/2	1/8	7-1/2	21	4
85	18436572	CC	10	.016	30	CH	J12Y	.035	-1/2	+1/2	1/8	7-1/2	21	4
85	153624	CC	2-1/2	.020	42	CH	N16Y	.035	-1/2	+1/2	1/8	7-1/2	12	4
95	18436572	VD	6	.016	30	AC	45S	.035	-1-1/2	+1/4	1/16	6-5/6	19-1/2	4
95	18436572	VD	6	.016	30	AC	45S	.035	-1-1/2	+1/4	1/16	6-5/6	19-1/2	4
95	18436572	VD	6	.016	30	AC	45S	.035	-1-1/2	+1/4	1/16	6-5/6	19-1/2	4
95	1342	VD	6	.016	30	AC	45S	.035	-1-2/3	+1/6	1/16	6-5/6	12-3/5	4
57	153624	VD	3	.020	39	CH	H10	.035	0	0	1/8	8	12	4
57	153624	VD	8	.016	31	CH	H18Y	.035	0	0	1/8	8	11	4
57	153624	VD	5	.016	31	CH	H18Y	.035	0	0	1/8	6-1/6	11	4
57	18436572	VD	TC	.016	34	CH	H18Y	.035	0	0	1/8	6-1/6	19	4
90	153624	VD	2	.020	39	CH	H14Y	.035	0	+1/2	3/16	6	12	5
90	18436572	VD	4	.016	29	CH	H14Y	.035	0	+1/2	3/16	6	18	5
90	18436572	VD	4	.016	29	CH	H14Y	.035	0	+1/2	3/16	6	18	5

Foreign Car Tune-Up Specifications

FOREIGN MAKE AUTOMOBILES MAKE AND MODEL						ENGINE SIZE					VALVE TAPPET CLEARANCE			IGNITION		SPARK PLUGS				SUSPENSION				
		Nationality	Air or Water Cooled	Engine Location	No. of Cylinders	Bore (ins.)	Stroke (ins.)	Displacement (cu. ins.)	Compression Ratio	Valve Location	Intake (ins.)	Exhaust (ins.)	Carburetor Make	Breaker Timing (deg.)	Breaker Gap (ins.)	Make	Type	Gap	Front or Rear Wheel Drive	Front Type	Rear Type	Caster (deg.)	Camber (deg.)	Toe-In (ins.)
Alvis	TD-21	Eng.	W	F	6	3.30	3.54	182.6	8.5-1	O	.009H	.012H	SU	5B	.015	CH	N5	.025	R	CO	LF	1-1/2	1	1/16
Armstrong-Siddely	(Early) Sapphire	Eng.	W	F	6	3.54	3.54	209.6	7.0-1	O	.006H	.006H	ST	5B	.015	CH	N8B	.028	R	CO	LF	O	2	3/16
Armstrong-Siddely	(Late) Sapphire	Eng.	W	F	6	3.82	3.54	243.5	7.5-1	O	.008H	.008H	ST	4B	.015	LE	HLN	.030	R	CO	LF	O	2	3/16
Austin	A40	Eng.	W	F	4	2.58	3.50	73.2	7.2-1	O	.015H	.015H	ZE	D	.012	CH	N8	.018	R	CO	LF	2-1/4	1	1/16
Austin	A50	Eng.	W	F	4	2.87	3.50	91.5	7.2-1	O	.015H	.015H	ZE	6B	.015	CH	N8B	.018	R	CO	LF	1-1/4	1	1/16
Austin	A55	Eng.	W	F	4	2.87	3.50	91.5	8.3-1	O	.015H	.015H	ZE	5B	.015	CH	N5	.025	R	CO	LF	3	3/4	O
Austin	A70	Eng.	W	F	4	3.13	4.38	134.2	6.8-1	O	.012C	.012C	ZE	6-1/2B	.012	CH	N8	.018	R	CO	LF	1-1/4	1	1/16
Austin	A90	Eng.	W	F	6	3.12	3.50	161.0	7.3-1	O	.012H	.012H	ZE	10B	.015	CH	N8B	.025	R	CO	LF	1-1/4	1/2	1/16
Austin	A135	Eng.	W	F	6	3.44	4.37	243.6	6.8-1	O	.012H	.012H	ST	9B	.012	LE	CN	.022	R	CO	LF	3/4	3/4	1/8
Austin-Healey	100	Eng.	W	F	4	3.44	4.38	162.2	7.5-1	O	.015C	.015C	SU	6B	.012	CH	NA8	.025	R	CO	LF	1-1/2	1	1/16
Austin-Healey	3000	Eng.	W	F	6	3.28	3.50	177.7	9.0-1	O	.012H	.012H	SU	5B	.015	CH	N3	.025	R	CO	LF	2	1	3/32
Bentley	Six	Eng.	W	F	6	3.62	4.50	279.0	6.8-1	OS	.006C	.012C	SU	D	.020	CH	N8	.025	R	CO	LF	3/4	O	1/16
Bentley	Eight	Eng.	W	F	8	4.10	3.60	380.0	8.0-1	O	HY	HY	NA	NA	.020	CH	RN8	.025	R	CO-TO	LF	O	1/4	3/32
B. M. W.	2.6L	Ger.	W	F	8	2.91	2.95	157.4	7.0-1	O	.010H	.010H	SO	8B	.014	BO	W225R	.036	R	TO	TO	5	1	1/8
Borgward	Isabella	Ger.	W	R	4	2.95	3.31	91.0	7.0-1	O	.008H	.008H	NA	D	.016	CH	L85	.025	R	CO	CO	3	1/2	O
Citroen	2CV	Fre.	AR	F	2	2.60	2.44	25.9	6.25-1	O	.006C	.008C	SO	8B	.015	CH	H9	.025	F	CO	CO	1/4	1-1/2	3/16
Citroen	15-19	Fre.	W	F	4	3.07	3.94	116.6	6.5-1	O	.006H	.008H	SO	12B	.015	CH	H10	.025	F	TO	TO	1-3/4	1	1/8
Citroen	(Early) Six	Fre.	W	F	6	3.07	3.94	174.9	6.5-1	O	.006H	.008H	SO	8B	.016	KL	FA50	.018	F	TO	TO	O	1	3/16
Citroen	(Late) Six	Fre.	W	F	6	3.07	3.94	174.9	6.5-1	O	.006H	.008H	SO	8B	.016	CH	H10	.018	F	TO	HP	O	1	3/16
Daimler	2-1/2L	Eng.	W	F	6	3.00	3.50	149.3	7.75-1	O	.013H	.013H	SU	9B	.015	LE	HLN	.020	R	TO	LF	O	1-1/2	1/8
Daimler	250	Eng.	W	F	8	3.00	2.75	152.5	8.2-1	O	.012C	.012C	NA	10B	.015	CH	N8	.025	R	CO	LF	NA	NA	NA
Datsun	Four	Jap.	W	F	4	2.88	2.80	72.5	8.2-1	O	.008H	.014H	NA	8B	.015	CH	NA8	.025	R	CO	LF	1	1	1/8
D. K. W.	2 cycle	Ger.	W	F	3	2.80	2.99	54.9	8.0-1	NU	NU	NU	SO	12B	.016	BO	M175TI	.024	F	T	T	O	2	1/16
Fiat	500	Ita.	AR	R	2	2.60	2.76	29.2	7.0-1	O	.005C	.005C	NA	10B	.018	CH	H9	.022	R	T	CO	9	1	1/8
Fiat	600	Ita.	W	R	4	2.36	2.20	38.6	7.0-1	O	.004H	.004H	WE	10B	.018	CH	H9	.025	R	T	CO	9	1	1/8
Fiat	1100	Ita.	W	F	4	2.68	2.95	66.4	7.0-1	O	.004C	.004C	WE	2B	.018	CH	H9	.030	R	CO	LF	2	1/2	1/8
Fiat	1200	Ita.	W	F	4	2.83	2.95	74.5	8.25-1	O	.004C	.004C	NA	D	.018	CH	H9	.030	R	CO	LF	2	1/2	1/8
Fiat	1500	Ita.	W	F	4	3.07	3.07	91.0	8.68-1	OC	.012C	.014C	NA	D	.018	CH	N3	.025	R	CO	LF	1	1/2	1/16
Fiat	1800	Ita.	W	F	6	2.83	2.89	109.5	8.8-1	O	.008C	.008C	NA	D	.016	CH	H9	.025	R	TO	LF	1-1/2	1	1/16
Ford	Anglia, Prefect	Eng.	W	F	4	3.19	1.91	60.8	8.9-1	O	.010H	.017H	SO	10B	.015	CH	N5	.030	R	CO	LF	3-1/2	1-3/4	1/8
Ford	Consul	Eng.	W	F	4	3.25	3.13	103.9	7.8-1	O	.014H	.014H	ZE	8B	.015	CH	N8B	.030	R	CO	LF	O	1/2	1/8
Ford	Zephyr, Zodiac	Eng.	W	F	6	3.25	3.13	155.8	7.8-1	O	.014H	.014H	ZE	8B	.015	CH	N8B	.030	R	CO	LF	O	1/2	1/8
Ford	Taunus	Ger.	W	F	4	3.23	2.79	91.4	6.8-1	O	.012H	.014H	NA	D	.017	CH	H10	.030	R	CO	LF	1-1/2	1/2	1/8
Hillman	Husky	Eng.	W	F	4	2.56	3.74	77.2	8.0-1	S	.010C	.014C	SO	7B	.016	CH	L10	.030	R	CO	LF	3-3/4	3/4	1/8
Hillman	Minx	Eng.	W	F	4	3.00	3.00	84.7	8.0-1	O	.014H	.014H	ZE	12B	.016	CH	N8	.030	R	CO	LF	3	3/4	3/16
Holden	Six	Aus.	W	F	6	3.00	3.13	132.5	6.5-1	O	.008H	.012H	ST	7B	.018	AC	44	.030	R	CO	LF	1-3/4	3/8	1/8
Holden	FC	Aus.	W	F	6	3.00	3.13	132.5	7.0-1	O	.008H	.012H	ST	7B	.018	AC	44	.030	R	CO	LF	0-2	1-2	1/8
Holden	EK	Aus.	W	F	6	3.06	3.13	138.0	7.25-1	O	.008H	.012H	ST	2B*	.014	AC	46	.030	R	CO	LF	0-2	1-2	1/8
Humber	Hawk	Eng.	W	F	4	3.19	4.33	138.2	7.5-1	O	.007H	.009H	ST	D	.015	CH	N8B	.025	R	CO	LF	1/2	3/4	1/8
Humber	Snipe	Eng.	W	F	6	3.44	3.25	180.9	8.0-1	O	.014H	.014H	ST	7B	.015	CH	N5	.025	R	CO	LF	1/2	3/4	1/8
Jaguar	Mark V 2-1/2L	Eng.	W	F	6	2.87	4.17	162.5	7.5-1	O	.012C	.015C	SU	5B	.012	CH	N8	.025	R	TO	LF	-3/4	2	1/8
Jaguar	Mark V 3-1/2L	Eng.	W	F	6	3.23	4.33	212.6	7.5-1	O	.012C	.015C	SU	5B	.012	CH	L10	.025	R	TO	LF	-3/4	2	1/8
Jaguar	Mark VII	Eng.	W	F	6	3.27	4.17	210.0	7.0-1	OC	.004C	.006C	SU	5B	.012	CH	17-L10S	.022	R	TO	LF	O	1	1/8
Jaguar	XK-120	Eng.	W	F	6	3.27	4.17	210.0	8.0-1	OC	.006C	.008C	SO	5B	.012	CH	17-L10S	.022	R	TO	LF	3	2	1/8
Jaguar	XK-150	Eng.	W	F	6	3.43	4.17	230.6	8.0-1	OC	.004C	.006C	SO	4B	.015	CH	17-N5	.025	R	TO	LF	1-3/4	3/4	1/16
Jensen	Six	Eng.	W	F	6	3.43	4.37	243.6	7.4-1	O	.012C	.012C	SU	9B	.012	CH	N8B	.035	R	CO	LF	2	1/2	1/16
Jowett	Four	Eng.	W	F	4	2.86	3.55	90.6	7.2-1	O	.002C	.006C	ZE	D	.014	CH	L10	.025	R	TO	TO	1-1/4	O	-1/8
Lancia	Appia	Ita.	W	F	4	2.68	2.95	66.5	7.8-1	O	.006C	.008C	SO	8B	.018	CH	N5	.022	R	CO	LF	O	1	1/8
Mercedes-Benz	180	Ger.	W	F	4	2.95	3.94	107.8	7.0-1	OC	.005C	.007C	SO	2B	.018	CH	L10	.040	R	CO	CO	3-1/2	1/2	1/16
Mercedes-Benz	190	Ger.	W	F	4	3.32	3.26	115.8	8.5-1	OC	.004C	.008C	SO	8B	.018	CH	730	.038	R	CO	CO	3-1/2	1/2	1/16
Mercedes-Benz	220	Ger.	W	F	6	3.15	2.87	133.6	8.7-1	OC	.003C	.008C	SO	5A	.014	CH	730	.038	R	CO	CO	3-1/2	1/2	1/16
Mercedes-Benz	300	Ger.	W	F	6	3.35	3.46	182.8	8.5-1	OC	.003C	.008C	FI	6A	.014	CH	730	.038	R	CO	CO	2-1/2	1/2	1/16
Metropolitan	1500	Eng.	W	F	4	2.87	3.50	91.5	7.2-1	O	.015H	.015H	ZE	11B	.015	CH	N8B	.024	R	CO	LF	2	1	1/16
M. G.	TC	Eng.	W	F	4	2.61	3.54	76.3	7.3-1	O	.019H	.019H	SU	D	.012	CH	L10S	.020	R	LF	LF	5-1/2	3	1/4
M. G.	TD	Eng.	W	F	4	2.61	3.54	76.3	8.3-1	O	.019H	.019H	SU	D	.012	CH	L10S	.020	R	CO	LF	2	1	O
M. G.	TF	Eng.	W	F	4	2.61	3.54	76.3	8.3-1	O	.012H	.012H	SU	D	.016	CH	NA8	.020	R	CO	LF	2	1	O
M. G.	Magnette	Eng.	W	F	4	2.88	3.50	90.9	8.3-1	O	.019H	.019H	SU	8B	.015	CH	N8B	.018	R	CO	LF	3	1	O
Morris	Minor	Eng.	W	F	4	2.28	2.99	48.8	8.3-1	O	.012C	.012C	SU	2B	.015	CH	NA8	.020	R	TO	LF	3	O	1/8
Morris	Cowley	Eng.	W	F	4	2.57	3.50	73.2	7.4-1	O	.015H	.015H	SU	4B	.015	CH	N8B	.018	R	TO	LF	3	1/2	1/8
Morris	Oxford	Eng.	W	F	4	2.88	3.50	90.9	8.3-1	O	.016C	.016C	SU	4B	.016	CH	N8B	.018	R	TO	LF	3	O	1/8
Morris	Six	Eng.	W	F	6	2.89	3.43	135.1	8.3-1	O	.015H	.015H	SU	5B	.012	CH	L10	.020	R	TO	LF	3	O	O
Opel	Rekord	Ger.	W	F	4	3.35	2.91	102.5	7.8-1	O	.008H	.010H	NA	D	.015	AC	45F	.035	R	CO	LF	1-3/4	1	1/16
Opel	Kapitan	Ger.	W	F	6	3.35	3.00	159.0	7.8-1	O	.008H	.010H	NA	D	.015	AC	45F	.035	R	CO	LF	1-3/4	1	1/16
Panhard	Dyna	Fre.	AR	F	2	3.35	2.95	51.9	7.2-1	O	.004C	.004C	SO	NA	.016	MA	34-5	.024	F	T	TO	1-1/2	O	-1/8
Peugeot	Four	Fre.	W	F	4	3.13	2.88	89.6	7.5-1	O	.004C	.008C	NA	9-1/2B	.016	AC	45FG	.025	R	T	CO	2-1/2	1/4	1/16
Porsche	356	Ger.	W	R	4	3.25	2.91	96.5	8.5-1	OC	.004C	.006C	NA	NA	.016	CH	L11S	.022	R	TO	TO	5	3/4	1/16
Renault	Dauphine	Fre.	W	R	4	2.28	3.15	51.6	8.0-1	O	.006C	.008C	SO	NA	.016	CH	L10	.025	R	CO	CO	10	1-1/2	1/8
Riley	Four	Eng.	W	F	4	2.88	3.50	90.9	8.3-1	O	.019H	.019H	SU	8B	.015	CH	N8B	.018	R	TO	CO	3	1	O
Rolls-Royce	Silver Dawn	Eng.	W	F	6	3.62	4.50	278.6	6.8-1	OS	.006C	.012C	ZE	D	.020	CH	N8	.030	R	CO	LF	3/4	1	1/16
Rolls-Royce	Silver Cloud	Eng.	W	F	6	3.75	4.50	298.2	6.6-1	OS	.006C	.012C	SU	2B	.020	LE	HNLP	.025	R	CO	LF	-1	1/2	1/16
Rolls-Royce	Phantom	Eng.	W	F	8	4.10	3.60	380.0	8.0-1	O	HY	HY	NA	NA	.020	CH	RN8	.025	R	CO-TO	LF	O	1/4	3/32
Simco	Aronde	Fre.	W	F	4	2.88	2.92	78.7	7.3-1	O	.008H	.010H	SO	4B	.018	MA	36	.027	R	CO	CO	2	1-1/4	1/8
Singer	Gazelle	Eng.	W	F	4	3.11	3.00	91.2	8.5-1	O	.012H	.014H	SO	8B-	.016	CH	N5	.030	R	CO	LF	3	3/4	3/16
Standard	Vangaurd	Eng.	W	F	4	3.35	3.62	127.6	7.5-1	O	.010C	.012C	SO	D	.015	CH	L10	.030	R	CO	LF	1	2	1/8
Sunbeam	Rapier	Eng.	W	F	4	3.11	3.00	91.2	9.2-1	O	.004H	.014H	ST	7B	.016	CH	N5	.025	R	CO	LF	3	3/4	3/16
Toyopet	Four	Jap.	W	F	4	3.03	3.07	88.5	7.5-1	O	.008H	.014H	NA	8B	.018	CH	NA8	.030	R	CO	LF	1	1	1/16
Triumph	Herald	Eng.	W	F	4	2.48	2.99	57.8	8.0-1	O	.010C	.010C	SU	12B	.015	LE	HLH	.025	R	CO	LF	O	2	1/8
Triumph	TR-3	Eng.	W	F	4	3.27	3.62	121.5	8.5-1	O	.010C	.010C	SU	4B	.015	LE	CNY	.025	R	CO	LF	O	2	1/8
Vauxhall	Victor	Eng.	W	F	4	3.13	3.00	92.0	7.8-1	O	.013H	.013H	ZE	9B	.020	AC	44	.030	R	CO	LF	1-1/4	1/4	1/8
Volkswagen	1952-54	Ger.	AR	R	4	2.96	2.52	69.0	5.8-1	O	.004C	.004C	SO	5B	.016	CH	L10	.025	R	TO	TO	2-1/2	1/2	1/16
Volkswagen	Jan. 1954-Aug. 1955	Ger.	AR	R	4	3.03	2.52	72.7	6.1-1	O	.004C	.004C	SO	7-1/2B	.016	BO	W175T1	.025	R	TO	TO	2-1/2	1/2	1/16
Volkswagen	Aug. 1955 - 1960	Ger.	AR	R	4	3.03	2.52	72.7	6.6-1	O	.004C	.004C	SO	7-1/2B	.016	BO	W225T1	.025	R	TO	TO	2-1/2	1/2	1/16
Volkswagen	1961-62	Ger.	AR	R	4	3.03	2.52	72.7	7.0-1	O	.008C	.008C	SO	10B	.016	BO	W175T1	.028	R	TO	TO	2-1/2	1/2	1/16
Volvo	Four	Swe.	W	F	4	2.95	3.15	86.6	7.3-1	O	.015H	.017H	ZE	2B	.017	AC	44	.030	R	CO	CO	3	O	O
Wolseley	Four	Eng.	W	F	4	2.88	3.50	90.9	8.3-1	O	.016C	.016C	SU	4B	.016	CH	N8B	.020	R	CO	LF	2-1/2	3/4	O
Wolseley	Six	Eng.	W	F	6	3.20	3.50	177.7	8.5-1	O	.012H	.012H	SU	5B	.015	CH	N3	.025	R	CO	LF	2-1/2	3/4	O

FOREIGN CAR REFERENCES

A - After
AR - Air cooled
AC - A C spark plugs
Aus. - Australian
B - Before top center
BO - Bosch spark plugs
C - Cold
CH - Champion spark plugs
CO- - Coil spring
D - Top dead center
Eng. - English
F - Front
FI - Fuel injection
Fre. - French

Ger. - German
H - Hot
HP - Hydro-Pneumatic
HY - Hydraulic
Ita. - Italian
Jap. - Japanese
KL - K.L.G. spark plugs
L - Liter
LE - Lodge spark plugs
LF - Leaf springs
MA - Marchal spark plugs
NA - Not available
NU - Not used
O - Overhead valves

OC - Overhead camshaft
OS - Overhead and side valves
R - Rear
S - Side valves
SO - Solex carburetor
ST - Stromberg carburetor
SU - S.U. carburetor
Swe. - Swedish
T - Transverse spring
TO - Torsion bars
W - Water cooled
WE - Weber carburetor
ZE - Zenith carburetor
* - 6B with Hydra-Matic transmission

JOB OPPORTUNITIES IN THE AUTOMOTIVE FIELD

For the young man with ability, educational background, and practical training, the automotive field offers a wide range of job opportunities.

It sometimes happens when choosing a vocation, that only a limited area of the field is observed. This is a mistake, because the first job should be considered as a stepping stone to a higher and better paying job.

Let's take a quick look at some of the job possibilities the automotive field offers:

AUTO MECHANIC

Were you to get a job in a retail automotive business, the first important job you are likely to get after you have had some training and experience as a helper, is Auto Mechanic.

The days of the "greaseball" mechanic are over. Most shops today are clean, well lighted and ventilated, and are equipped with labor-saving tools and testing devices, which make the jobs easier and more interesting. Modern mechanics wear neat working clothes.

An auto mechanic's job calls for a broad range of both light and heavy repair work. It requires the ability to diagnose and locate trouble, and to make the right adjustment or replacement. A good auto mechanic is well paid, and his work is always in demand.

SPECIALTY MECHANIC

A Specialty Mechanic is a serviceman who has become a specialist in some one phase of repair work. You can specialize in diagnosis and tune-up, electrical repair, body work, automatic transmissions, front end and steering or any of a number of other kinds of service.

SHOP FOREMAN

A Shop Foreman is the man in charge of mechanics in an automotive dealership, independent service garage, or private garage of a transportation company. He is usually an expert mechanic who has been promoted to foreman. His job involves scheduling and routing repair work as it comes into the shop--supervising and instructing mechanics--inspecting finished repairs--and being responsible generally for quality work and satisfactory shop operation.

SERVICE MANAGER

A Service Manager is the department head, supervising all service employes and responsible for customer satisfaction. He should be a good manager and should have the ability to get along well with both employes and customers. In addition to department supervision, he must try to build up business for the shop with advertising and sales promotion activities.

MOTOR VEHICLE SALESMAN

Motor Vehicle Salesman is the job for you if you have a special liking for selling. Experience in the service department gives you an excellent background for sales work because, if you know the mechanics of a vehicle you can do a much better job of talking about the car or truck, demonstrating it and comparing it with other competing makes.

SALES MANAGER

A Sales Manager has charge of the entire selling activity of a dealership, including service. This is one of the best positions in the retail automotive business usually held by a man who has made a success of selling and who has managerial ability.

PARTS MANAGER

A Parts Manager for a car or truck dealer has an important job ordering, stocking and selling replacement parts and accessories. He supplies the shop in his dealership and sells parts and accessories at wholesale to the independent repair garages in his community. Training in service work and parts sales are valuable experience for this job.

JOBBER SALESMAN

Jobber Salesman is an interesting occupation in the parts field, a job that should appeal to a sales-minded young man with automotive service training. A jobber salesman, representing a wholesale house, travels over a certain territory selling the products of several manufacturers to all kinds of automotive repair and supply shops.

EMPLOYMENT WITH MANUFACTURERS OF MOTOR VEHICLES

Employment with Manufacturers of Motor Vehicles is sometimes open to men with mechanics training and other qualifications. This applies to such positions as: Factory District Manager, Factory Service Manager, Factory Service Representative, Factory Parts Manager and Factory Service Instructor.

EMPLOYMENT IN AUTOMOTIVE FACTORIES

Employment in Automotive Factories can make use of training in automotive mechanics in such jobs as Final Assembly Car Inspector, Final Assembly Repairman, Dynamometer Tester, Experimental Driver, Driver Mechanic, and Engineering Garage Mechanic and Repairman.

TECHNICAL TEACHER

Technical Teacher, either in a public school or as a factory service instructor, is an interesting career. You might be employed by the factory to train service personnel in new developments, or you might teach automotive mechanics in schools.

DRIVER OF A TRUCK OR BUS

Driver of a Truck or Bus is a job employing over 6 million persons, the second largest occupational group in America. Many operators of large fleets of trucks or buses prefer that their drivers have automotive mechanics training. Such drivers take better care of their vehicles; they can make emergency repairs if necessary; and in general they are more reliable.

INSURANCE ADJUSTER AND CLAIM EXAMINER

Insurance Adjuster and Claim Examiner are jobs that insurance companies like to fill with young men who, in addition to other qualifications, have automotive service training.

REPRESENTATIVES

Representatives of many companies which supply the automotive industry are frequently bright, high-caliber young men who began their careers with training in automotive mechanics.

OWNERS OF SERVICE STATIONS OR SPECIALTY REPAIR SHOPS

Owners of Service Stations or Specialty Repair Shops can certainly use automotive service training to advantage. If you have any ambition to become this kind of independent business man, training in automotive mechanics can help you achieve your goal.

AUTOMOTIVE DEALERS

Automotive Dealers, men who operate their own businesses and are frequently leaders in their communities, often get their start as automotive mechanics.

You can see from the foregoing that training in automotive mechanics could be your key to any one of a number of interesting careers. You can see that automotive service is a big, broad, many-sided business with enough opportunities to interest almost anyone who has the desire and determination to make good in a worthwhile job.

Remember, your most valuable asset is the ambition and determination to succeed. By alertness, application and perseverance you can gain knowledge and skill for which there is an eager market offering many satisfying rewards.

ACKNOWLEDGMENTS

In the preparation of this encyclopedia, almost every manufacturer in the automotive industry was consulted. Without exception they extended to us the utmost in cooperation. Information, records and illustrations have been available to us. As a result, we have herein a complete library of automotive service knowledge.

A list of every source of such assistance would result in a directory of the industry. The editors and publishers therefore wish to thank the industry and the individual companies for their valued assistance. It is our hope that this encyclopedia will be helpful to the industry as a whole as well as students, teachers and automotive enthusiasts.

Some of the manufacturers who have been particularly cooperative are as follows:

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We hope that their efforts and ours will result in a better understanding of their products in the U.S.A. with resultant better service and improved customer satisfaction.

Alvis, Ltd., Armstrong Siddeley Motors, Ltd., Austin Motor Co., Ltd., Ford Motor Co., Ltd., General Motors-Holden's, Ltd., Jaguar Cars, Ltd., Jowett Cars, Ltd., M. G. Car Co., Ltd., Morris Motors, Ltd., The Rover Co., Ltd., Rootes, Ltd., Singer Motors, Ltd., Vauxhall Motors, Ltd., Daimler-Benz, Fiat, NSU Werke, Renault Regie Nationale, Volkswagenwerke, Zundapp-Werke.

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